TECHNICKÁ UNIVERZITA V LIBERCI
Fakulta textilní

Jednota protikladů

Bakalářská práce

Studijní program: B3107 – Textil
Studijní obor: 3107R006 – Textilní a oděvní návrhářství

Autor práce: **Daria Kharenkova**
Vedoucí práce: doc. Ing. Martina Viková, Ph.D.

Liberec 2019

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Unity of opposites

Bachelor thesis

Study programme:	B3107 – Textil
Study branch:	3107R006 – Textile and Fashion Design - Textile Design and Technology
Author:	**Daria Kharenkova**
Supervisor:	doc. Ing. Martina Viková, Ph.D.

Liberec 2019

TECHNICKÁ UNIVERZITA V LIBERCI
Fakulta textilní

Zadání bakalářské práce

Jednota protikladů

Jméno a příjmení: **Daria Kharenkova**
Osobní číslo: T15000554
Studijní program: B3107 Textil
Studijní obor: Textilní a oděvní návrhářství
Zadávající katedra: Katedra designu
Akademický rok: **2018/2019**

Zásady pro vypracování:

1. Zpracujte přehled dosavadních poznatků v oblasti retroreflexních materiálů a jejich potenciálních aplikací na textiliích a studii retroleflexe.

2. Proveďte studii potencionální aplikace retroreflexních tisků, respektive tiskem.

3. Vyberte vhodnou metodiku testování vybraných stálostí retroreflexních tisků.

4. Zpracujte inspirační studii návrhu.

5. Na základě výše uvedených studií navrhněte oděv s retroreflexními prvky pro běžné odívání – vrchní ošacení.

6. Navrhněte další postup.

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REGAN, M.A., LEE, J.D., YOUNG, K.L. Driver distraction, Theory, Effects and Mitigation, CRC Press 2009

WORDENWEBER, B., WALLASCHEK, J., BOYCE, P., HOFFMAN, D.D. Automotive Lighting and Human Vision, Springer 2007

NASSAU, K. Color for Science, Art and Technology, Elsevier, 1998

Vedoucí práce: doc. Ing. Martina Viková, Ph.D.
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V Liberci 5. listopadu 2018

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13. 4. 2019 Daria Kharenkova

PODĚKOVÁNÍ

Ráda bych poděkovala své vedoucí bakalářské práce paní docence Martině Vikové za odborné vedení, cenné rady a vstřícnost při konzultacích k vypracování bakalářské práce a panu docentovi Michalu Vikovi za rady a pomoc při realizaci experimentů s retroreflexními vzorky.

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ANOTACE

Tato bakalářská práce se věnuje nalezení technologických a tvůrčích řešení pro aplikaci bezpečnostních reflexních prvků na vrchní ošacení pomocí textilního tisku. Vzhledem k tomu, že tisky mohou ovlivnit vlastnosti textilního materiálu, nejlepší varianta musí být zvolená pro snížení možné modifikace.

Jedním z nejdůležitějších cílů této práce je dosáhnout nejlepší výsledky reflexních potisku a objevit je-li této potisky jsou užitečné pro každodenní nošení.

Teoretická část práce je zaměřená na hloubkové studium materiálů s vysokou viditelností a problematickou aplikaci reflexních pigmentu. Pro výběr nejvhodnějších tiskových metod studovány různé tiskové techniky.

Experimentální část obsahuje aplikace tisku a měření vzorku různé barvy a různého materiálu pro dosažení lepších výsledku. Vlastní motivy pro tisk, koláže, skice a šablony jsou vytvořené pro finální výsledek.

Na závěr jsou všechna měření vyhodnocena a vybraný návrh je vypracován na šablony finálních oděvu a výsledná vrchní ošacení je ušité.

KLÍČOVÁ SLOVA

oděvy s vysokou viditelností, retroreflexe, reflexní pigmenty, tisk, viditelnost, design, technologie, vodoodpudivost

ANNOTATION

The aim of this bachelor thesis is to find technological and design solutions for applying safety reflective elements on outer clothes by textile printing. As prints can affect textile material properties, the best option should be chosen to minimize modifications. One of the main goals of this work is to achieve the best results from retroreflective ink and to discover how profitable is this ink for everyday use.

The theoretical part focuses on deep studies of high visibility materials and problematic retroreflective inks application. Additionally, different printing techniques are studied for the selection of the most suitable printing method.

The experimental part contains the printing application and measurements of samples with different color and fiber material to achieve the best results. Moreover, it involves the creation of designs for prints, mood boards, sketches and patterns for final garment.

In conclusion, all measurements are evaluated, and design is selected to apply on the pattern of final garments, the outer clothes sewn as a result.

KEYWORDS

high visibility material, retroreflectivity, reflective inks, printing, visibility, design, technology, water repellency

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INTRODUCTION

Recently, all manufacturing processes began developing at a lively pace. Nowadays people trying to learn more about new technologies and their using. Industry 4.0. is coming ahead, textile production becoming more sustainable and eco-friendlier. Trends are becoming long term, and consumers prefer buying quality items that can be used for several years. All worldwide trends are focused on making fashion more sustainable and hi-tech without losing a perspective of design.

The purpose of this bachelor thesis is understanding of importance usage of high visibility materials and retroreflective inks in everyday wearing apparel. Moreover, this bachelor thesis is focused on detailed studies of retroreflective inks and its application and appearance on outer clothing with selected completed designs. Usage of high visibility materials is pretty wide both for safety reasons, and designs selection.

In the theoretical part, this work is focused on studies of high visibility materials, color vision, and psychology of seeing. It also covers the problematic application of retroreflective prints as prints can affect the main properties of textile materials, suitable printing techniques and studying printing in general. Furthermore, it describes types of fixation and after treatments.

In the experimental part, an individual design is processed, the type of material is selected, and the printing technique is chosen to apply prints on the textile. Creation of designs involves technological and inspiration aspects to find a solution to make the designs work in both fields. Also, the experimental part involves measurements of applied retroreflective inks on different materials and have after treatment procedure. The design, color selection and sketches for outer clothes are described. Best samples were selected for further processing, and the final garment is created and made.

THEORETICAL PART

1. RETROREFLECTIVE AND HIGH VISIBILITY MATERIALS

1.1. RETROREFLECTION

Retroreflection is the optical phenomenon in which light is guided to a direction that is opposite and parallel to that of the originating source, and the passive optical structures that help achieve this aspect are called retroreflectors. Retroreflectors are commonly used in a wide scope of applications such as road safety, metrology, and interferometers. [1]

1.2. TYPES OF REFLECTION

There are three types of reflection: specular reflection, diffuse reflection and retroreflection, which are illustrated in Figure 1.

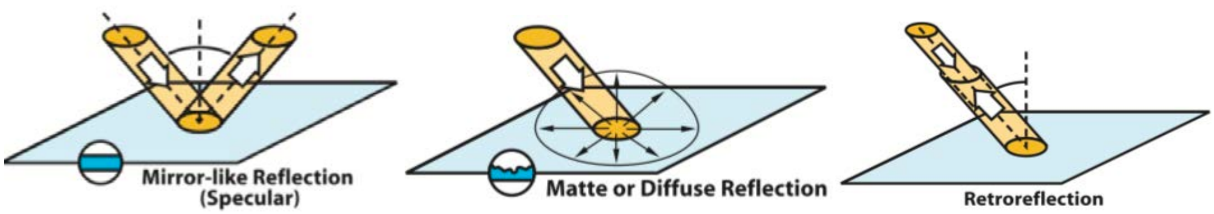


Figure 1: Retroreflection returns the light to its source [2]

Specular/Regular reflection is a mirror-like reflection of rays of light. Here the rays of light which are reflected from a smooth and bright object such as a mirror, are reflected at a definitive angle and each incident ray which is reflected along with the reflected ray has the same angle to the normal as the incident ray. Thus, this type of aspects causes the formation of an image.

Diffuse/Irregular reflection is a uniform reflection of light with no directional connection for the viewer (a matte surface such as cardboard). Diffuse reflection begins from a combination of internal scattering of light, the light is absorbed and then re-emitted, and external scattering from the rough surface of the object. An illumination model must handle both direct diffuse reflection and light coming directly from a source to a surface and then reflected the observer. And indirect diffuse reflection that is a light coming from a source, being reflected a surface, then reflected another surface and finally to the viewer. [2]

Retroreflection is the phenom of light rays striking a surface and being redirected back to the source of light. By definition, light sources release some amount of their energy in the form visible light. An ideal point light source delivers its light equally in all directions. If a perfect sphere light source were enclosed in a perfect field, every point on the sphere would be illuminated by an equal amount of brightness or light intensity.

A directed light source, such as a car's headlights, directs its' light in a cone around the direction that it is denoted. If one of your headlights put out a total amount of light energy equal to the point source, and it was enclosed in the same perfect field, the points on which your headlight shines would be brighter than each object illuminated by the point source. [3]

1.3. HIGH VISIBILITY MATERIAL

High-visibility materials are used to make an object, animal or person visually stand out from the surrounding environment. For example, as a European Notified Body, SATRA is responsible for certifying different types of high-visibility products to prove that they meet the requirements of the EU Directive (89/686/EEC) on personal protective equipment (PPE). The sun's ultraviolet rays react with the fluorescent colors of the material to create a glowing appearance. The effect of this glow is stronger at times of poor light, like dusk and dawn. However, it can also work using ultraviolet light from different sources, such as car headlamps. Some reflective material is retro-reflective, which means light bounces back to its source, so a car's headlights will reflect back to the driver or anyone standing near the light source. Another material is made using glass bead technology, which scatters light coming from any angle.

Hi-vis clothing can be made from either material and comes in a range of colors, including red, pink, blue and green. However, for safety purposes, it is often the most effective fluorescent colors such as yellow and orange that are used. [4]

Types of high visibility material:

Fluorescent

- Emit light from other absorbed light, which has lower energy than absorbed radiation.
- Good daytime, dawn, & dusk benefits
- Poor at nighttime

Chemiluminescence

- Chemical reaction (i.e. light sticks)
- Short-lived/No daytime benefit

Phosphorescent

- Does not immediately re-emit the radiation it absorbs
- Glow-in-the-dark (needs to be exposed to light)
- Short-lived/No daytime benefit

Retroreflective

- Dawn & dusk benefits
- Great nighttime benefits-poor daytime
- Requires light source

As for retroreflective materials, they appear brightest to an observer located near the original light source. Since very little light is scattered when the light is returned, retroreflective materials enhance the contrast of the wearer for an observer located near the original light source. [5]

1.4. RETROREFLECTIVE MATERIALS

The reflective material is most effective when lights are lighting directly at it. As the lights' angle increases away from 90 degrees, the material becomes less effective Figure 2. If lights are coming from an angle of more than about 3 degrees off a direct line in any direction from the object (bicyclist or pedestrian) the reflector's effectiveness is seriously decreased. It is important to be sure either to use a wide piece of reflective material to increase the area that can reflect light or use multiple reflective devices.

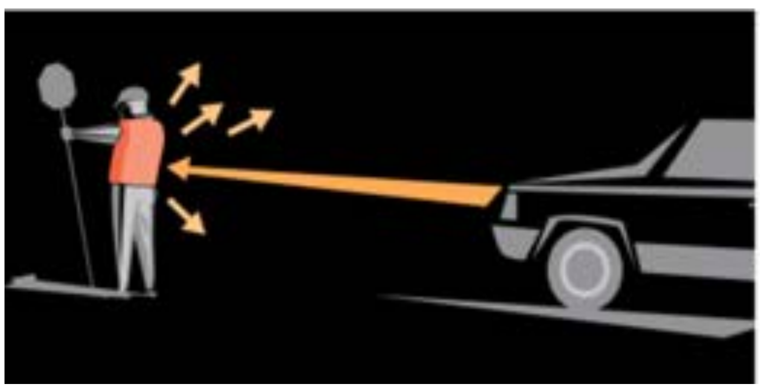


Figure 2: Scattered Reflection [5]

Usage of retroreflective materials is the most effective way to increase conspicuity at night or under low-light conditions. However, these materials are not conspicuous in daylight.
Retroreflective material is made using tiny glass beads which reflect light directly back toward its source, from a much wider angle than reflective material.

Traffic signs and pavement markings are retroreflective. Retroreflective materials can be incorporated into clothing, helmets, bike equipment, backpacks or attachable strips.
Retroreflective material can help create a visual “signature” pedestrian at night or under low-light conditions Figure 3. The signature helps the motorist identify the "thing up ahead" as a

pedestrian rather than a fence post, motorcycle or snowplow. If the time it takes the motorist to detect and recognize a pedestrian or bicyclist can be reduced, there is more time to react and to avoid a crash if necessary. [6]

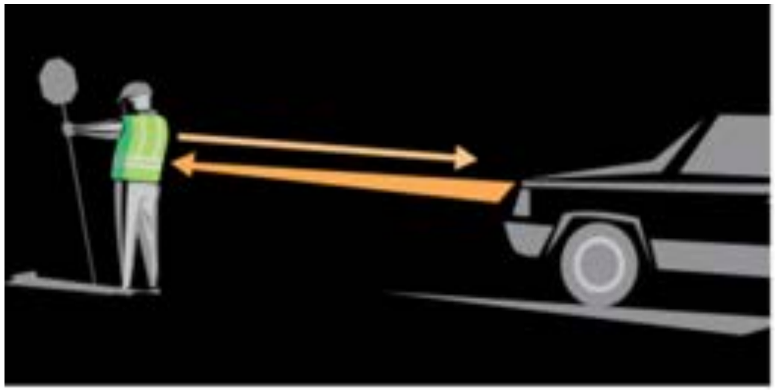


Figure 3: Retroreflection [5]

2. APPLICATION FOR HIGH VISIBILITY MATERIALS

2.1. COLOR VISION

Firstly, it is important to understand how vision works and identifies the color. The primary function of color vision is to provide the identification of objects in the surroundings. In real life conditions, the context in which things are seen varies markedly from time-to-time. The spectral distributions of the lights that come from objects depend on their spectral reflectivity and on the spectral distribution of the light which illuminates them. Accordingly, the same object would look truly different from one time to the next if the sensations were directly correlated with the spectral distributions arriving from them. The facts of color matching have to be considered and then going on to the more difficult question of what factors guide the appearance of objects in complex daily situations.

Color vision serves to helps people to recognize objects. The persisting attribute of an object is not the amount or spectral distribution of the light that arrives from it but the reflectance spectrum of the object. For example, a lump of coal in sunlight appears black, while a piece of chalk in the shade looks white even though the coal may reflect much more light than the chalk. This is referred to as "lightness constancy". Similarly, when a number of objects of different spectral reflectance are taken from one illuminant to another, the color of the objects tends to persist. This is referred to as "color constancy". These terms are somewhat misleading because neither lightness nor color is ever completely constant. Sometimes objects appear very different in different illuminants. [7]

2.2. THE PSYCHOLOGY OF SEEING

The first step in the process of "seeing" is searching or exploring. In this stage, the brain must take information from the scanning eye and identify the stimulus it has learned to recognize as being important enough to approve further attention.

The second step is detection. In this phase, the brain must sort through the thousands of bits of information the optic nerve is sending. It must defect the object to which it orders to pay closer attention and then lead the eye to focus.

The third step is an evaluation. The brain has just directed the eyes to focus more attention on the object in question. The brain now has to search its long-term memory to see if it identifies this object from earlier experience.

The next step is a decision. After recognizing the object, the brain has to analyze all the data coming through the eyes to estimate the objects speed, position in traffic, distance away from the vehicle, direction of riding and other factors and to decide upon an appropriate plan of action.

The final step is action. After fixing the location of the pedestrian the motorist must react to what has been seen based on decisions made in the fourth step. If the motorist reacts soon enough, a crash can be avoided. [8]

2.3. STUDIES OF BEST PLACEMENT FOR RETROREFLECTIVE ELEMENTS

The biological motion contains knowledge about several different emotions, intentions, personality traits and biological attributes of the agent. The human visual system is highly sensitive to biological motion and capable of extracting this information from it. It’s not necessary for a human to see everything to recognize a person. That’s why reflective material on the biomotion points is a major component. [9]

The University of Michigan Transportation Research Institute studied high-visibility work apparel at night. Researchers made a remarkable discovery: The placement of reflective material on the garment can be more significant than brightness and color. Adding material to motion points, like the arms, greatly increased conspicuity – how readily visible or noticeable something can be. [10]

Nowadays, the following standards are applied to PPE (Personal protective equipment) high-visibility products marketed within Europe:

- EN ISO 20471:2013 + A1:2016 – High visibility warning clothing for professional use
- EN1150: 1999 – Visibility clothing for non-professional use
- EN13356: 2001 – Visibility accessories for non-professional use

The standard for professional use high-visibility garments allows the manufacture of three classifications of a garment. Each classification is based on minimum allowances for both fluorescent material and tape that can be used in producing a garment. The retroreflective performance requirements for ‘separate performance’ tape (material intended to exhibit retro-reflective properties) and ‘combined performance’ tape (material intended to exhibit both background fluorescence and retro-reflective properties). Accordingly, producers have to always make sure that the retroreflective material that intend to use meets market’s demands. Buyers of high-visibility garments may also specify that retroreflective tapes are able to withstand specific cleaning treatments, usually appropriate to the type of contamination that their apparel may experience. For example, clothing that becomes contaminated with oil may require dry cleaning. It is, therefore, important to determine whether a retroreflective material has the ability to withstand repeated solvent immersion. [11]

EN ISO 20471 is an international standard that imposes requirements on visible workwear for employees in high-risk areas as mentioned above. Using the right safety workwear is important and must be prioritized. Even if working in areas where visibility is important only takes place during a short part of the working day. EN ISO 20471 is divided into three classes (A, B and C) Figure 4, in accordance to the risk zone workers in and to how well the product is able to protect the employee. It is the visibility requirement – and thus the requirement for the area consisting of reflectors and fluorescent materials – that determines which class will be chosen. [12]

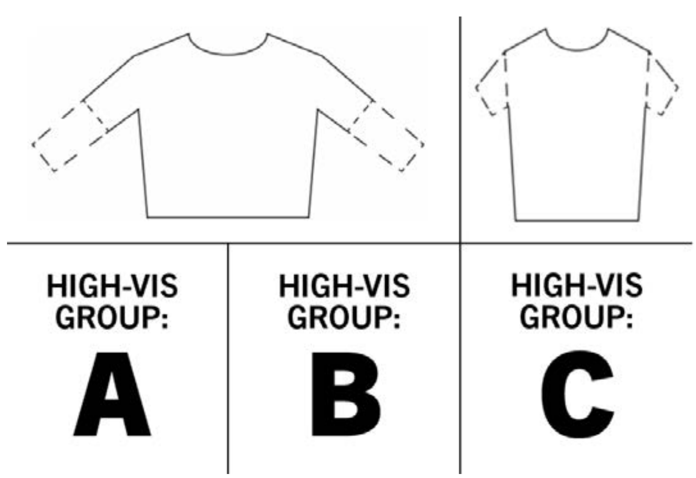


Figure 4: Three classes of high-vis [12]

Class 1 high-visibility clothing can be used in situations with a low risk of collisions and accidents. Class 1 high- visibility clothing is not suitable for work on public roads, but is suitable for work in full or partial daylight within a company's premises. Maximum traffic speed 30 km/h.

Class 2 work clothing provides good visibility for roadworks, courier services and twilight work. Class 2 high- visibility clothing is suitable for work on public roads with a maximum traffic speed of 50 km/h.

Class 3 high-visibility clothing is mandatory when working in the dark. Visible at traffic speeds up to 90 km/h. This optimum visibility greatly reduces the risk of accidents.

SATRA can carry out independent checks on retroreflective materials to guarantee that they meet the minimum performance levels that are required by standards. Additionally, testing can be arranged to determine whether materials have the durability requirements that may be demanded by individual manufacturers or users of high visibility garments. [13]

As for standard EN1150: 1999 for non-professional use clothing requires less assessment in demand as the clothing is used in less demanding situations. The high visibility is not just a function to use the right materials on the garments, but the design of the garment also influences aspects of visibility. [14]

As for American National Standard for High-Visibility Safety Apparel and Headwear (ANSI/ISEA 107-2010) is a standard established by American National Standards Institute, Inc. Construction, maintenance, utility, emergency responders, airport ramp personnel and other workers are routinely exposed to the hazards of low visibility while on the job. This standard provides guidelines for the selection and use of high-visibility safety apparel such as shirts, rainwear, outerwear, safety vests, and headwear to improve worker visibility during the day, in low-light conditions and at night. It also provides an authoritative guide for the design, color, photometric and physical performance, use and test methods of high-visibility safety apparel including safety vests, hi-vis jackets, bib overalls, pants, and gears. Based on the different work environment, the standard classified the performance into three classes.

ANSI 107-2015 standard includes a "Type" structure that keeps off-road ("Type O"), roadway ("Type R"), and public safety ("Type P") garments separate by application and work environment. The types are further broken down into classes 1, 2 or 3. Three classes help the user to choose the proper garments based on expected work environment risks.

For example, TYPE R, CLASS 3 garments present the highest level of safety, for workers who will be exposed to high-speed traffic or reduced sight distances. It requires a minimum of 1240 in^2 (smallest size 1000 in^2) of background material and 310 in^2 of retroreflective or combined performance material. However, CLASS E as a supplement type of ANSI 107, can be applied to rain pants, bib pants, shorts, etc. It can Combine with a Class 2 vest for an ANSI Class 3 ensemble, or a Class 3 vest to attain higher level visibility. It requires a minimum of 465 in² of background material and 109 in² of retroreflective or combined performance material. [15]

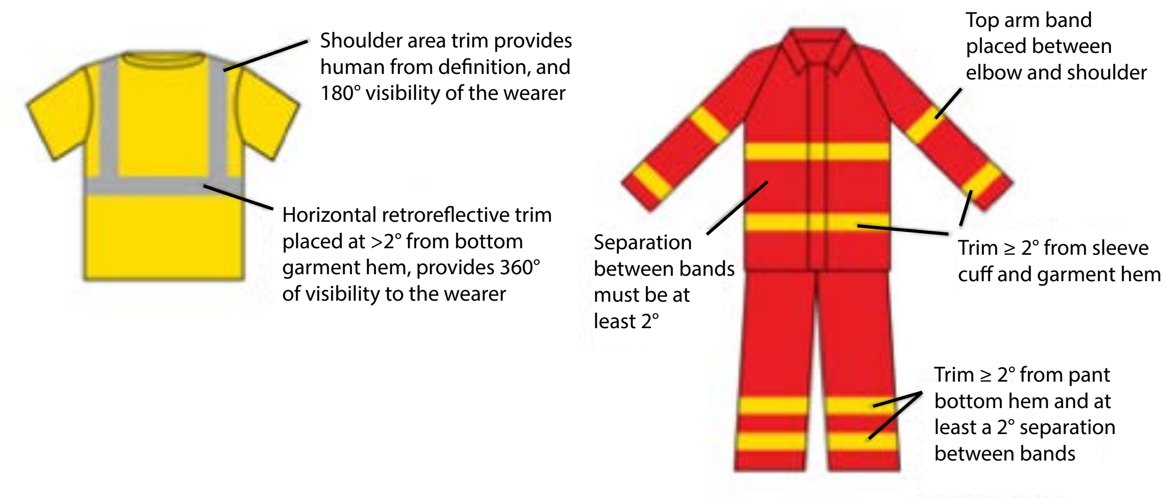


Figure 5: Example of required garments [5]

According to standard, ANSI/ISEA 107-2010 retroreflective material must be placed on a garment to achieve 360° visibility, with at least one retroreflective band encircling the torso. Garments without reflective material encircling the sleeves are now required to have 150 cm² (23.25 in²) of reflective material in the shoulder area, to provide 180° visibility of the wearer Figure 5. The shoulder area is defined as measuring 15 cm (5.9 in) down from the shoulder high point, on the front and back of the garment. The requirement of 23.25 in² is the total amount of reflective material required in the shoulder area including the front and back of the garment, e.g., shoulder area retroreflective material amount front + rear ≥ 23.25 in². [16]

3. The potential application of retroreflection prints

3.1. Reflective inks

Reflective screen-printing inks have been in the market for plenty of years now. The most common type of reflective ink is the pure grey/metallic reflective, as well as the reflective ink, which has some additional silver shimmer added for a flashy look that is more attractive in appearance when viewed in regular daylight. These inks contain microscopic glass beads that have been partially coated with a reflective metal, which is what makes them reflect the light that hits the beads back to the viewer. Some manufacturers also have ‘colored’ reflective inks, where the pigment is added to the ink, however, the reflective property of this ink is greatly decreased because the colored pigments cover up the reflective coating of the beads.

One of the first things that need to be approached when printing with reflective inks is which mesh count to use. This determines the type of design, or detail, that can be printed. Suggested wire mesh number is up to mesh 125 per inch (depends on the ink), the higher mesh counts can be used for a lessened effect. One of the common mistake printers make when using a direct print reflective is to print an underbase. It is important not to use the underbase or print-flash-print, despite of the color of the garment, because part of the process in printing reflective directly onto a garment is that the clear part of the ink, the vehicle or carrier of the glass beads, should be pushed into the garment, thus letting the beads to ‘float’ on top of the garment and provide the most reflectivity. If an underbase is used, the absorption of the bead carrier into the garment cannot happen and the print cannot achieve the optimal reflectivity. This is also true if the reflective ink is printed, flashed, and printed again. Instead, there is a suggestion to print stroking the ink twice without flashing and always using as much pressure as possible, which is the opposite to correctly printing standard inks. [17]

3.2. A GENERAL DEFINITION OF PRINTING

Textile printing is the most distinct and important of the processes used to introduce color and design through textile fabrics. From an analytical point of view, it is a method of bringing together a design idea, one or more colorants, and a textile substrate, usually a fabric, using a technique for applying the colorants with some accuracy.

The word ‘printing’ indicates a process that uses pressure, being derived from a Latin word-meaning pressing. It basically means to produce (a text, picture, etc.) by applying inked types, plates, blocks, or the like, to paper or other material either by direct pressure or indirectly by offsetting an image onto a standard roller. [18]

3.2.1. SCREEN-PRINTING

- Hand screen and semi-automatic screen-printing

The practice of hand screen-printing is now mainly restricted in colleges of art, small-scale units, and the high fashion industry, as it is a craft rather than a productive process of printing. Printing is carried out on a flat, solid table covered with a layer of resilient felt and a washable blanket (usually coated with neoprene rubber) Figure 6. Heat for drying the printed fabric may be provided either under the blanket or by hot air fans above the table. Before a design can be printed, it must be represented on the screens in a suitable form. One screen is needed for every color in the design, except when the fabric is dyed to the background color (known as the ground) before or after printing, or when a third color is produced by one color falling on another. When the background color is printed it is termed the 'blotch'. The steps necessary to take an artist's original design to the stage of being ready for screen-printing are detailed.

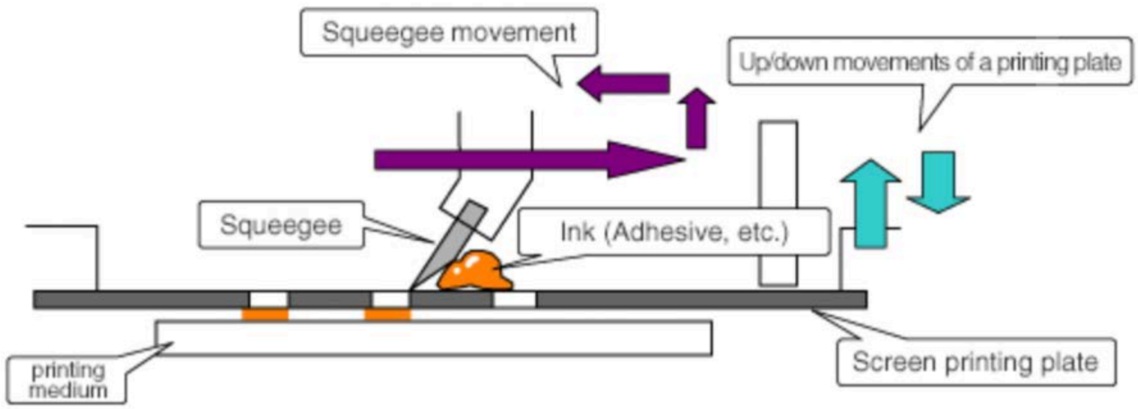


Figure 6: Semi-automatic screen-printing [19]

- Fully automatic flat-screen printing

In order to increase the speed of flat-screen printing, it was necessary to devise a method of printing all the colors simultaneously. Unfortunately, flat screens are not suitable coloration units for a truly continuous process, and in all the successful machines for fully automatic flat-screen printing the color is applied through the screens while the fabric is stationary Figure 7. All the screens for the design (one screen for each color) are positioned carefully along the top of a long endless belt, known as a blanket. A machine intended to print traditional furnishing designs might have space for 15 or more screens. The width of the gap between the areas printed by any two adjacent screens must be a whole number of lengthways designs repeats. This need not necessarily be the same as the lengthways screen repeat as there may be several design repeats per screen repeat; for example, where there are three design repeats per screen repeat, the gap between adjacent screens need only be one- third of a screen repeat.

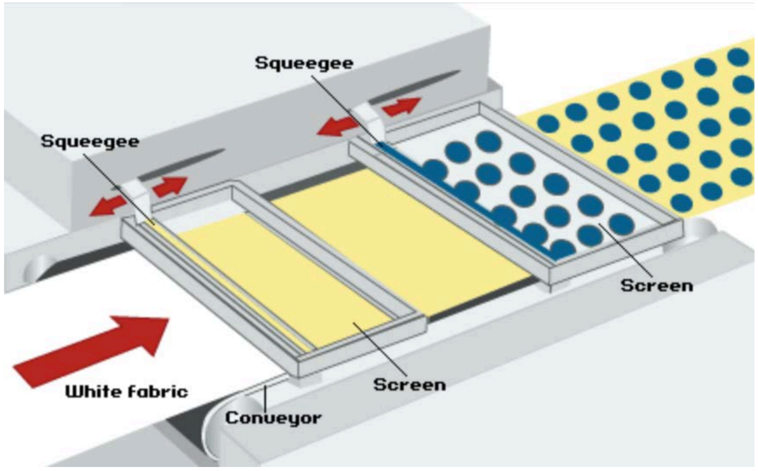


Figure 7: Fully automatic flat-screen printing [20]

- Rotary-screen printing

Fully automatic flat-screen machines cannot be described as operating continuously, because their printing action is in fact intermittent. The continuous movement of the fabric has been achieved by moving the screens along with the fabric while printing, but the use of rotary-screen machines has proved to be a simpler and more economical means of achieving this purpose.

In rotary-screen printing, continuous rotation of a cylindrical screen while in contact with the fabric ensures genuinely continuous printing Figure 8. Print paste is fed into the inside of the screen, and during printing is forced out through the design areas with the aid of a stationary squeegee.

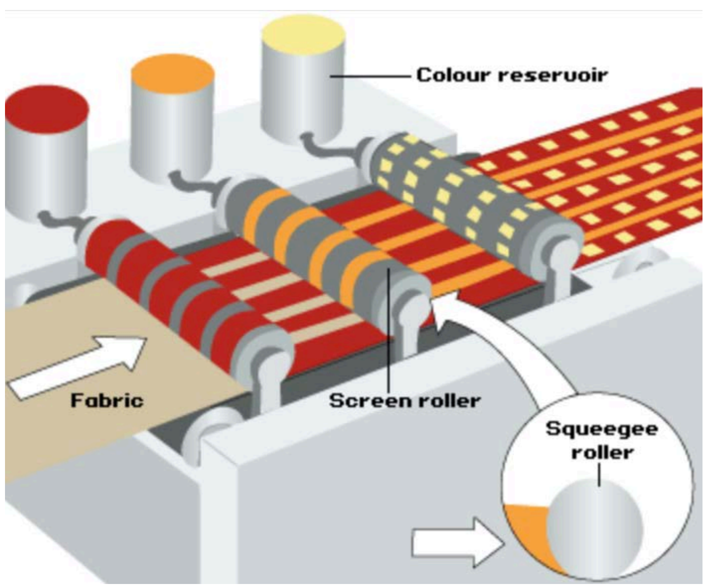


Figure 8: Rotary-screen printing [20]

- Computer-aided designs

By far the most important developments in the printing of recent years have been in the field of computer-aided design (CAD). Associated with these advances has come laser engraving, and also the proofing of designs on paper or fabric before screen engraving. All these depend upon the successful digitization of the design, that is, the conversion of design information into binary code in a form that can be stored in the memory of a computer.

3.2.2. Transfer printing

- Sublimation transfer

This method depends on the use of a volatile dye in the printed design. When the paper is heated the dye is preferentially adsorbed from the vapor phase by the textile material with which the heated paper is held in contact. This is commercially the most important of the transfer-printing methods.

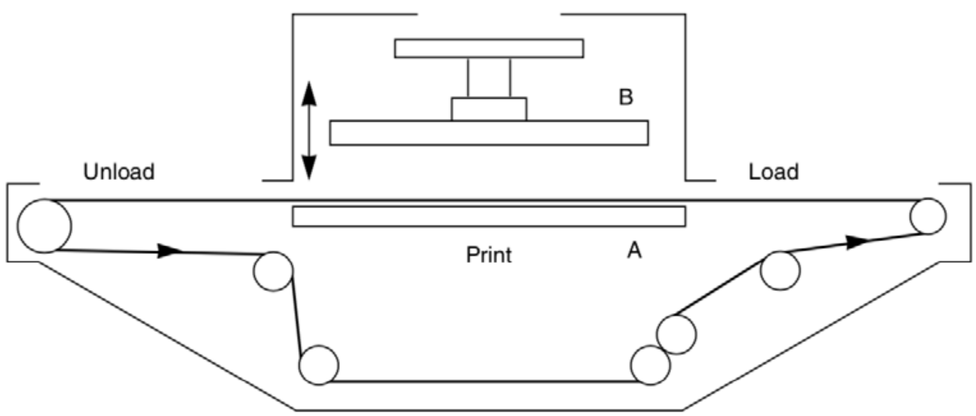


Figure 9: Flat-bed press [21]

- Melt transfer

This method has been used since the 19th century to transfer embroidery designs to fabric. The design is printed on paper using waxy ink, and a hot iron applied to its reverse face presses the paper against the fabric. The ink melts on to the fabric in contact with it. This was the basis of the first commercially successful transfer process, known as Star printing, developed in the late 1940s in Italy. It is used in the so-called ‘hot-split’ transfer papers widely used today in garment decoration.

- Film release

This method is similar to melt transfer with the difference that the design is held in an ink layer, which is transferred completely to the textile from a release paper using heat and pressure. Adhesion forces are developed between the film and the textile, which are stronger than those between the film and the paper. The method has been developed for the printing of both continuous web and garment panel units but is used almost exclusively for the latter purpose. In commercial importance, it is comparable with sublimation transfer printing.

- Wet transfer

Water-soluble dyes are incorporated into a printing ink, which is used to produce a design on paper. The design is transferred to a moistened textile using carefully regulated contact pressure Figure 11. The dye transfers by diffusion through the aqueous medium. The method is not used to any significant extent at the present time.

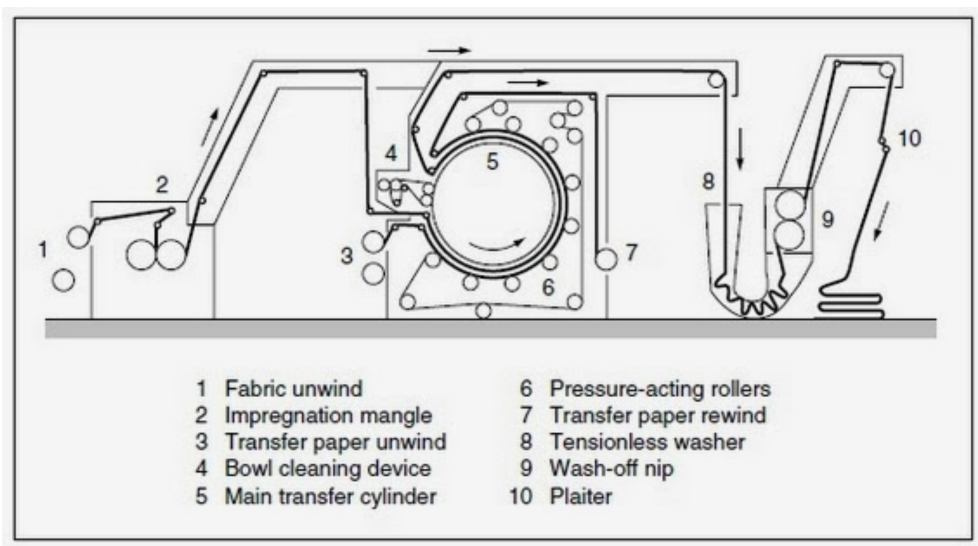


Figure 10: Wet transfer-printing machine (DewPrint) [22]

3.2.3. DIRECT PRINT COLORATION

- Pigment printing

In pigment printing, insoluble pigments, which have no affinity for the fiber, are fixed on to the textile with binding agents in the pattern required. This description is perhaps oversimplified, but it does obviously set pigments apart from dyes that are absorbed into the fiber and fixed there as a result of reactions specific to the dye.

The economic importance of pigments in printing is substantial: since around 1960 these have become the largest colorant group for textile prints. More than 50% of all textile prints are printed by this method, mainly because it is the cheapest and simplest printing method. After drying and fixation, these prints meet the requirements of the market. The washing process carried out on classical prints to remove the unfixed dye, thickening agents and auxiliaries, is not normally necessary when using the pigment printing technique.

- Other fiber printing (cellulosic fiber, polyester fiber, cellulose acetate fiber, acrylic fiber, polyamide fiber, protein fiber)

3.2.4. DISCHARGE, RESIST AND SPECIAL STYLES

- Discharge printing

Printed materials with large areas of ground color can be produced, the depth, levelness, and penetration of which would be difficult, if not impossible, to obtain by a direct printing process. Delicate colors and intricate patterns can be reproduced on grounds of any depth, with a clarity and sharpness that have become the hallmarks of this style.

The extra processes required and the additional costs of discharge pastes mean that production costs are higher, but the aesthetically superior results give the product a higher value and enable profit margins to be maintained or even improved. The higher costs of discharge printing are often offset when applied to long-lasting designs used for scarves, ties, cravats and dressing gowns.

- Resist printing

Reserve or resist printing is related to discharge printing in that the end results are often indistinguishable. The resist style, however, offers the advantage that dyes of great chemical stability, which could not be discharged, can be resisted to give prints of high fastness standards.

The justification for both styles lies in the aesthetic appeal of a white or colored pattern on colored grounds, an effect that very often could not be reproduced by any other technique. The difference, therefore, between discharge and resist printing is not one of appearance, but of the process. In resist printing, the resisting agent is printed on to the undyed fabric and effectively prevents the fixation or development of the ground color, which is subsequently applied by an appropriate ‘dyeing’ technique, such as dyeing, padding or overprinting.

The result can be either a white resist or a colored resist, where a selected dye or pigment is added to the resist paste and becomes fixed to the fiber during subsequent processing.

- Special styles printing

This section is devoted to a selection of those printing styles which, although not now produced by the majority of commercial printing establishments, still have some interest and significance for specialized outlets. Some knowledge of the special techniques employed in the production of such styles leads to a deeper understanding and appreciation of the art of textile printing and stimulates the constant search for new effects. [23]

3.3. APPLICATION FOR RETROFLECTION PRINTS

During the deep studies of every printing method was discovered that there are just a few suitable techniques, which can be used for reflective prints. Computer-aided designs, as well as sublimation transfer printing, is not possible to use according to their mechanical properties. The suitable techniques are screen-printing, melt transfer, and film release.

3M™ Scotchlite™ Reflective Material Transfer Films are designed for use on safety garments and in athletic and casual wear. When properly used, Scotchlite reflective material – transfer films help enhance the visibility of the wearer in nighttime or low- light conditions when illuminated by a light source, such as headlights, by returning the light back toward the original source and reaching the automobile driver's eye. Scotchlite reflective material – transfer films are composed of wide angle, exposed retroreflective lenses bonded to a heat activated adhesive. Some products contain a plastic liner to protect the adhesive side that must be removed before lamination and a paper liner to protect the retroreflective side during handling. [24]

Die cutting is suggested, although it can also be hand-cut or guillotined. For Scotchlite reflective material – transfer films with a white paper liner, the protective white paper liner should not be used as the carrier when applying (laminating) plotter cut and weeded images, the exposed liner may adhere to certain fabrics at suggested lamination temperatures.

Screen-printing is the most common way to print reflective inks. The inks that are used to print directly onto the garments include beads floating in the ink that are facing any which way and the ones that reflect back are only the portion of the beads that appear to be facing the light. There is no way to get them all to align and face one way when they are dissolved in the ink mixture.

The reflective materials that are used for the highway workers are specially made at a factory that aligns all the beads onto a flat surface before coating the side that is face up with a metalized coating. The beads are then all adhered to a substrate, such as the safety tape, with the coated-side down. The beads are all still aligned in the identical direction and the part facing outwards is the clear glass part with the metalized coating in the back, just like a mirror. This tape is then sewn onto the safety garment with the aligned beads providing far greater reflectivity than the direct screen-printed inks.

The only way to get the same intense reflectivity as the safety vest tape is to use a reflective transfer process. The beads are all aligned so they are facing the carrier sheet and then a transfer adhesive is printed onto the garment and partially cured. The carrier sheet with the beads is then placed with the pre-printed adhesive side down on the garment and heat transferred using a transfer press. During the transfer process, the ink melts and becomes the adhesive for the beads on the carrier sheet. Once the transfer is cool, the carrier can be removed, revealing the custom reflective image. It can be observed that design can reflect as much as 10 times brighter than the direct printed reflective inks. [25]

4. THE SUITABLE TESTING METHOD FOR RETROREFLECTION PRINTS

4.1 OVERVIEW OF REFLECTION AND RETROREFLECTION MEASUREMENTS

Measurement of reflection and retroreflection of a surface includes commonly reception of reflected light from a field of the surface when illuminated by a light source Figure 11.

By means of calibration, the signal from the receiver is expressed as a reflection or retroreflection characteristic, whose definition requires a proportion between a reflected amount of light and an incoming quantity of light.

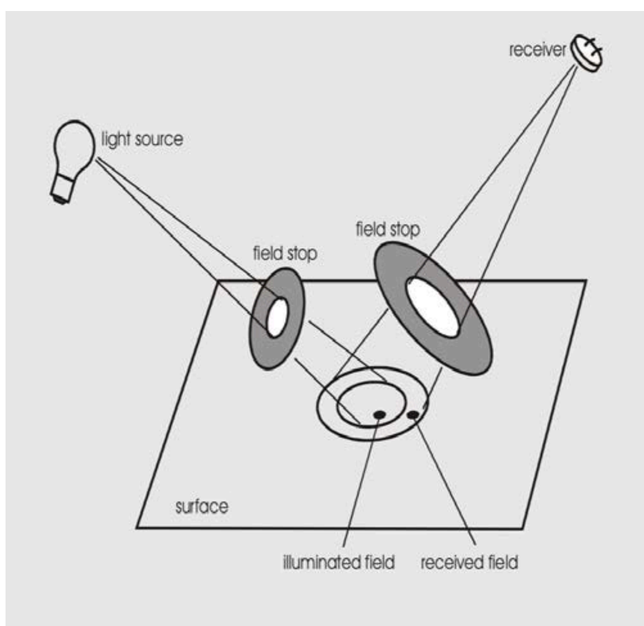


Figure 11: Light source, receiver, field stops and fields [26]

The specular reflection measurements, for example, analyze the light that is ejected from a surface into a unique direction. The Law of Reflection states that the angle of an incident ray of light is equal to the angle of reflection; granted that the surface is stable, reflecting, and free of defects.

Rough or matte materials manage to exhibit diffuse reflection when struck by incident light. This refers to the scattering of wavelengths in multiple directions and is associated with decreased color saturation and vibrancy. The outcome of a measurement depends on the spectral composition of the illumination and, consequently, a particular characteristic is defined with reference to for instance CIE illuminants D65, representing an incandescent light source or daylight with a color temperature of 6500 K. Refer to ISO/CIE 10526.

Reflection measurements are generally used in product development and quality control for visual materials and tools such as plastic films, coated glass, and phosphor plates.

The color of the reflected light might be relevant as a measure of the color of the surface. The perception of color is primarily defined by two objective factors: the wavelengths of light that are reflected from a surface and the color of the illuminating light. White light is a compound of lights of different wavelengths in the visible spectrum. A surface will absorb and reflect the proportions of these wavelengths dependent upon its color. [26] [27]

4.2. DIFFERENT METHODS OF MEASURING REFLECTIVITY

For the past few years, the value of precisely measuring the reflectance properties of reflective materials and solar reflector materials has improved due to the fact that more and more different kinds of materials appeared on the market. The commercial instruments available to measure reflectance are classified into laboratory scale spectrophotometers and portable reflectometers. In what follows the devises used for measure reflectance that are commercially available are described.

4.2.1 SPECTROPHOTOMETERS

A spectrophotometer is a photometer, a device for measuring light intensity, that can measure intensity as a function of the light source wavelength. They are commonly used for a wide range of applications to measure transmittance, absorptance, the reflectance of solutions and opaque materials. The main advantage of a spectrophotometer is the fact that the reflectance can be measured over the entire spectral range.

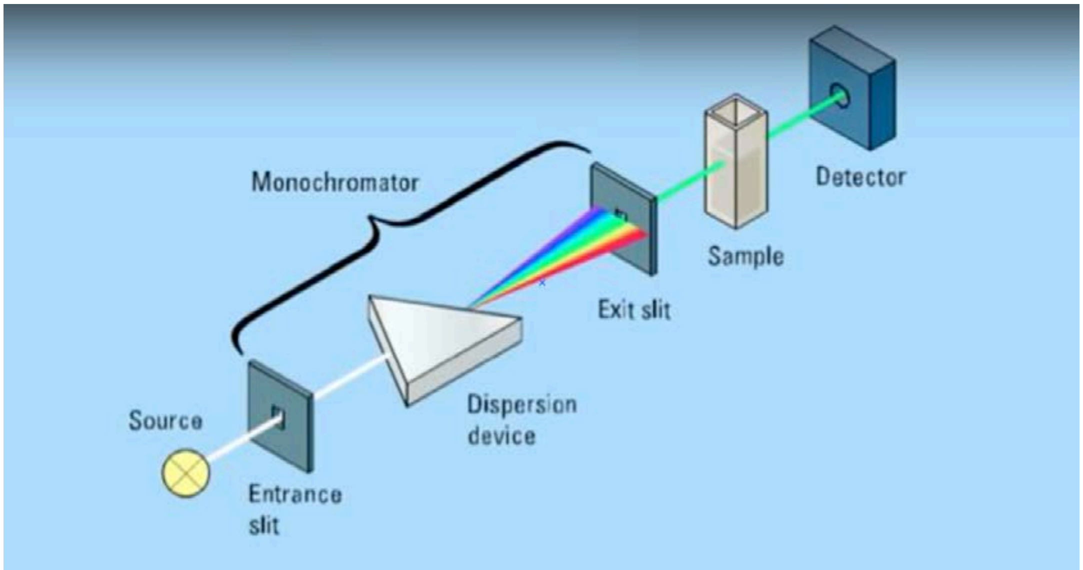


Figure 12: UV-vis spectroscopy [28]

The main disadvantages are that the detectors used in spectrophotometers are broadband, meaning they react to all the light that reaches them. If there are impurities in the sample that reflect light, an erroneous reading may be recorded. Stray light also makes a decrease in absorbance and reduces the linearity range of the instrument. [29]

4.2.2. Reflectometers

Reflectometers are devices that measure the intensity of the light source after reflection on a sample without wide spectral information, that is, they are equipped with light sources that radiate only one or a few narrow wavelength lines or bands. The wavelength range of lines or bands should be between λ = 500 nm and λ = 660 nm.

After calibration with a known reflectance reference standard, the measured intensity is automatically transformed into a reflectance reading by correlating the measured flux intensities of reference standard and sample. Reflectometers are typically prepared to measure specular reflectance. However, reflectometers that are equipped with integrating spheres may be also suitable for hemispherical reflectance measurements if their sphere is large enough.

Figure 13: Portable reflectometer [30]

Portable instruments of this kind are also useful for relative measurements in quality control or cleanliness measurements in the field, even with a small sphere, depending on the level of precision that is required. [31]

5. FIXATION AND AFTER-TREATMENT PROCESSES

Typically, when a fresh-made textile print is washed soon after printing and drying, a substantial part of the color is removable. An appropriate fixation step is therefore so important. Complete fixation can infrequently be achieved, however, and the removal of unfixed dye, thickening and auxiliary chemicals in a subsequent washing process is usually required.

Printed dyes are usually fixed by steaming processes, the steam providing the moisture and rapid heating that brings about the transfer of dye molecules from the thickener film to the fiber within a reasonable time.

The efficiency with which these processes of fixation and washing are carried out is vitally important, to both the quality and the cost of the prints. The proportion of faults in the final product that are introduced at this stage can be disastrously high.

6. WATERPROOF OR WATER-RESISTANT

6.1. WATER-RESISTANT

Water-resistant clothing means that garments have a waterproofing repellent coating on the outside to stop water absorption. Nevertheless, they are not fully tape seamed, meaning that water can still get in through areas such as the zip. It is also important to consider how windproof a for example jacket is, as this will help to keep the user warm. Water-resistant items do usually have a wind-proofing element, but not to the extent of a waterproof item. This kind of garment would be best when something light for occasional light rain or day trips is needed.

6.2. WATERPROOF

Waterproof clothing is formed using a membrane or coating that serves as a barrier that rain cannot penetrate. The face part of the fabric is also treated with a durable water repellent (DWR) finish that prevents raindrops from soaking that surface and compromising the breathability of the underlying membrane or coating. DWR is a coating added to the fabric to make them hydrophobic. Most factory-applied treatments are fluoropolymer based. Durable water repellents are commonly used in combination with waterproof breathable such as Gore-Tex to restrict the outer layer of fabric from becoming saturated with water. [32] [33]

6.3. LAMINATION AND COATING

The natural or synthetic fabrics are laminated or coated to become waterproof and breathable. Laminates is a waterproof/breathable membrane is bonded to the underside of a garment's shell fabric. Because it’s a durable construction (the membrane is protected by the face fabric), a laminate is found in outerwear designed for extreme environments.

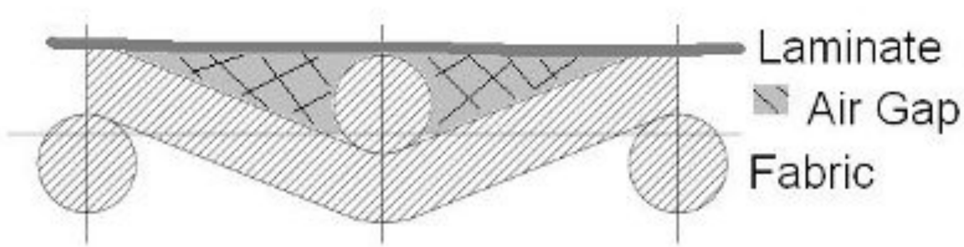


Figure 14: Schematic of a laminated textile [34]

A coating is a waterproof/breathable film is dispersed across the inner surface of a shell fabric. Coated constructions are lighter and more affordable than laminates; the tradeoff may be lesser appearance and durability than a laminate.

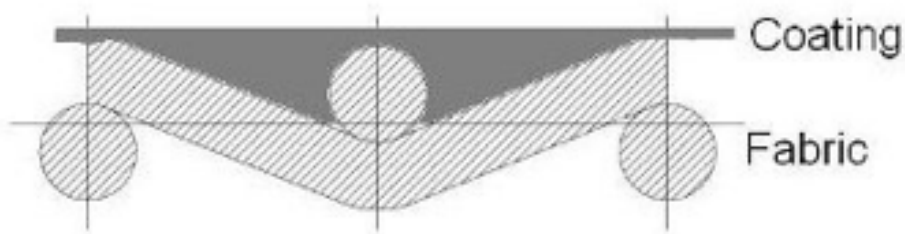


Figure 15: Schematic of a coated textile [34]

The fabrics such as wax, polyurethane (PU), rubber, fluoropolymers, polyvinyl chloride (PVC) or silicone elastomer are laminated to or coated with waterproof materials. [35] [36]

7. THE AIM OF THE WORK

This bachelor thesis is based as mentioned above on detailed studies of the visibility of retroreflective inks and its application on outer clothes. The retroreflective inks are not really known in Europe and need further studies.

Also, it was important to find a balance in technological and design appearance by knowing every aspect of both fields. As nowadays all worldwide trends are focused on making fashion more sustainable and hi-tech without losing a perspective of design. Therefore, the second part of this bachelor will be devoted to finding technological and design solutions.

EXPERIMENTAL PART

In the experimental part, an individual design, color selection and sketches for outer clothes are processed. The laboratory tests involve printing with special retroreflective ink and measurements of retroreflectivity on different materials with different ink concentration that applied on samples. Also, after treatment of processed material is provided by silicone water repellent. Best samples are selected for further processing, and final garments are made.

8. Materials for samples

Considering the main idea of this bachelor thesis different materials were selected for the experimental part to achieve results. As mentioned before the goal of this bachelor thesis is understanding of importance usage of high visibility materials and retroreflective inks in everyday wearing apparel. The material selection is one of the important steps that should be well studied. Therefore, the material with three basic colors is provided: an alternative to black is dark navy blue, grey (lava) and white. Also, as navy blue material is used as raw material for a raincoat, another color alternative (dark khaki) is provided to have a better understanding of contrasts between them.

Parameters of textile №1. Technical description:

Color: Navy blue

Fiber material: 52 % CO 48% PA

Woven design: Plain weave

Weight (10 cm/10 cm): 2,659 g

Basic weight: 0,2659 kg. m^{-2}

Thickness: 0,48 mm

Bulk density: 553,958 kg/ m^{-3}

Ends per centimeter: 47 warp threads per centimeter

Picks per centimeter: 35 weft threads centimeter

Warp crimp: 13 %

Weft crimp: 17 %

Degree of warp crimp: 1,113

Degree of weft crimp: 1,117

Percentage of warp crimp: 10,15%

Percentage of weft crimp:10,5%

Parameters of textile №2. Technical description:

Color: Lava

Fber material: 58 % VI 42% PA

Woven design: Twill weave

Weigh (10 cm/10 cm): 1, 265 g

Basic weight: 0,1265 kg. m^{-2}

Thickness: 0, 27 mm

Bulk density: 468,518 kg/ m^{-3}

Ends per centimeter: 30 warp threads per centimeter

Picks per centimeter: 23 weft threads per centimeter

Warp crimp: 8 %

Weft crimp: 15 %

Degree of warp crimp: 1,092

Degree of weft crimp: 1,115

Percentage of warp crimp: 8,4%

Percentage of weft crimp: 10,3%

Parameters of textile №3. Technical description:

Color: White

Fiber material: 55 % CO 45% PES

Woven design: Twill weave

Weight (10 cm/10 cm): 1,586 g

Basic weight: 0,1586 kg. m^{-2}

Thickness: 0,376 mm

Bulk density: 421,808 kg/ m^{-3}

Ends per centimeter: 38 warp threads per centimeter

Picks per centimeter: 26 weft threads per centimeter

Warp crimp: 6 %

Weft crimp: 10 %

Degree of warp crimp: 1,106

Degree of weft crimp: 1,1

Percentage of warp crimp: 9,6%

Percentage of weft crimp: 9%

Parameters of textile №4. Technical description:

Color: Dark khaki

Fiber material: 52 % CO 48% PA

Woven design: Plain weave

Weight (10 cm/10 cm): 2,553 g

Basic weight: 0,2553 kg. m^{-2}

Thickness: 0,46 mm

Bulk density: 555 kg/ m^{-3}

Ends per centimeter: 49 warp threads per centimeter

Picks per centimeter: 36 weft threads per centimeter

Warp crimp: 19 %

Weft crimp: 21 %

Degree of warp crimp: 1,119

Degree of weft crimp: 1,121

Percentage of warp crimp:10,63%

Percentage of weft crimp: 10,8%

9. Laboratory tests

The purpose of experimental part is to achieve the best results in two opposite aspects: design and technology. From the side of technology, it is important to understand units of measurements, specific of printing, after treatments and measurements of retro reflection. From design: inspirations, mood boards, sketches, patterns and finalization of product.

Climatic conditions for experimental part:

p= 1009,3 hPa

t= 22,6 C

um= 29,7%

Textile ink: TEXILAC CAT EYE made by Company Horizont KP s.r.o.

Product description: Water-based ink for textile printing. Good opacity, retro reflective effect. [37]

Substrates	• Cotton 100% The substrates may be white or colored
Th/cm	Max. 43 (109 Th/inch)
Emulsion	• ZERO - IN ASTRA • ZERO - IN UNIVERSAL PLUS
Squeegee	Square edge Squeegee hardness 60 - 65 Shores
Curing	150°C for 3 minutes
Thinner	In case, max 2% Water
Thickening agent	In case, max 1% TEXILAC AD- DENSANTE 346 NEW
Retarder	In case, max 3% TEXILAC RITARDANTE
Colors	Max 1% TEXILAC COLORANTI or ECOTEX P PIGMENTI
Fixing agent	In case, 2% ECOTEX FIX 50
Cleaning	Water or SCREENCLEAN ST
Storage	• Away from direct sunlight • At a temperature between 15- 35°C
Package	1 Kg

Table 1: Application process of textile ink (TEXILAC CAT EYE)

The different concentration of applicated ink was used for achieving the best results during the printing.

Navy blue samples	Lava samples	White samples	Dark khaki samples
50 g/kg*	500 g/kg***	500 g/kg***	1 kg*
50 g/kg**	600 g/kg***	600 g/kg***	1 kg* 2 layers
500 g/kg***	700 g/kg***	700 g/kg***	
600 g/kg***	800 g/kg***	800 g/kg***	
700 g/kg***	900 g/kg***	900 g/kg***	
800 g/kg***	1 kg*	1 kg*	
900 g/kg***			
1 kg*			
1 kg* 2 layers			
1 kg*2 layers with separate curing			
1 kg* 3 layers			
1 kg* 3 layers with separate curing			

Table 2: Different quantity of applicated ink

* with thickening agent and retarder

** without retarder but with thickening agent

*** with thickener, thickening agent and retarder

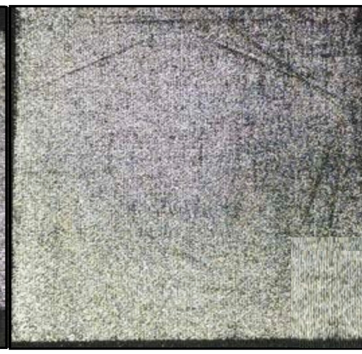
Navy blue samples:

50 g/kg**

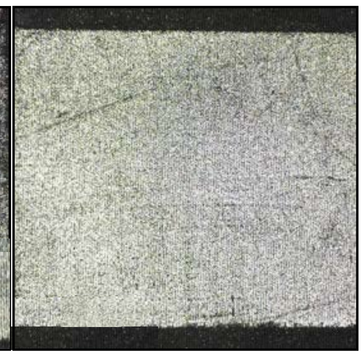
50 g/kg*

500 g/kg***

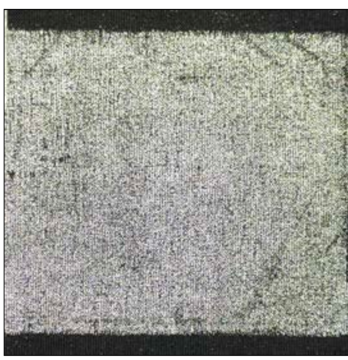
600 g/kg**



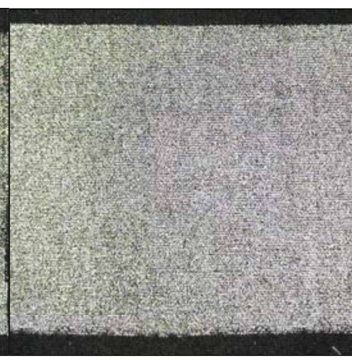
700 g/kg*



800 g/kg***



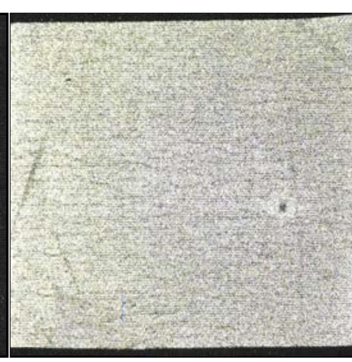
900 g/kg***



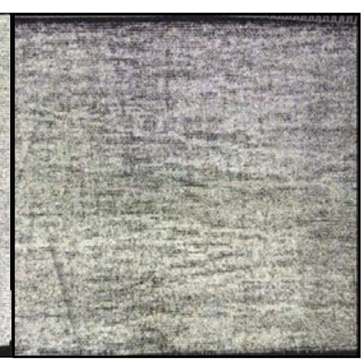
1 kg*

1kg *2 layers

1kg *2 layers
with separate curing



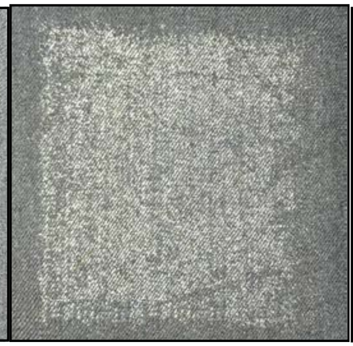
1kg *3 layers



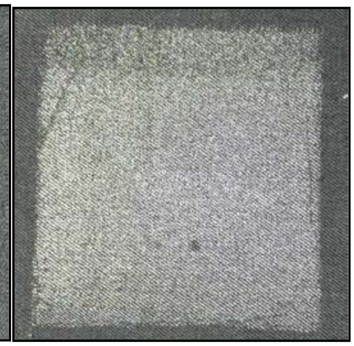
1kg *3 layers
with separate curing

Lava samples:

500 g/kg**

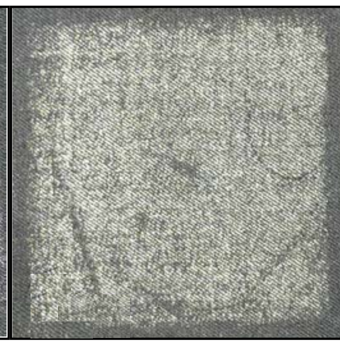


600 g/kg*



700 g/kg***

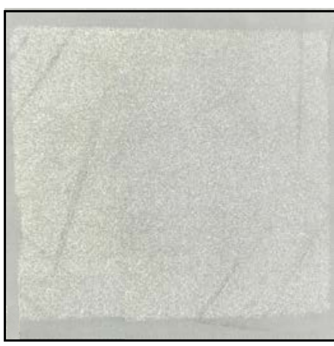
800 g/kg**



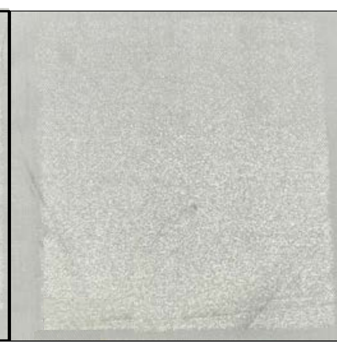
900 g/kg*

1 kg*

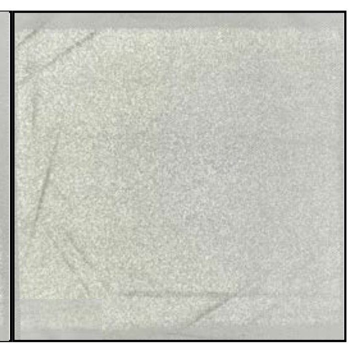
White samples:



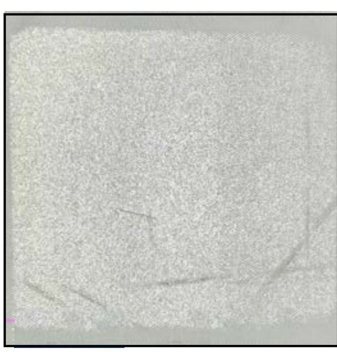
500 g/kg**



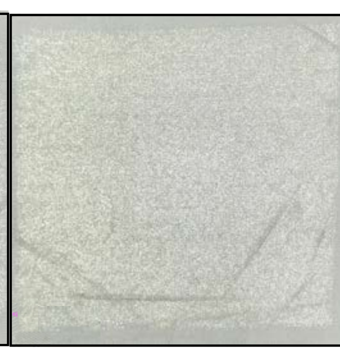
600 g/kg*



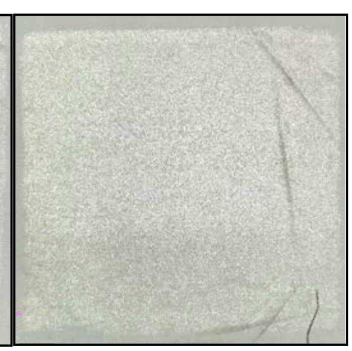
700 g/kg***



800 g/kg**

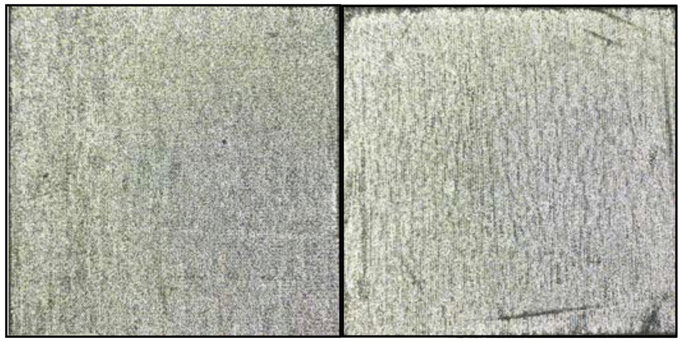


900 g/kg*



1 kg*

Dark khaki samples:



1 kg* 1 kg* 2 layers

It can be observed that sample with thickening agent and retarder is meeting better result than a sample without retarder. Also, the visual effect has become more illuminant with an increasing quantity of textile ink and a decreasing quantity of thickener. Despite that, the quality of each print cannot be evaluated precisely as a different level of pressure was applied.

White samples have achieved the best results from a visual perspective as white color is more visible. When light strikes a surface, some of its energy is reflected and some are absorbed. The color that human perceives indicates the wavelength of light being reflected. White light includes all the wavelengths of the visible spectrum, so when the white color is being reflected, that means all wavelengths are being reflected and none of them absorbed, making white the most reflective color. [38]

Lava samples have achieved the worst results, because of fiber material (58 % VI 42% PA). It can be observed that prints dispersed in material structure. As a substrate for the textile ink has to be cotton, the reason is evident.

The retroreflectivity increases with the number of layers but curing has to be done in one action. Additionally, the number of layers has to be a maximum of 3 layers. Otherwise, the retroreflectivity will decrease for both reasons.

As navy blue and dark khaki have the same fiber material, exclusively the best samples for dark khaki material was printed for comparing the effect for different color.

According to the results that were achieved some samples were printed less. For more detailed studies samples with higher retroreflectivity were processed in the microscope (SEM). Nevertheless, white samples weren't selected because a fiber material won't be used in the final garment.

10. SCANNING ELECTRON MICROSCOPE (SEM)

SEM is an indirect method. A great advantage is a possibility of obtaining images with great depth of field. The possibilities of using SEM in the textile industry scope from the observation of the fiber surface and the internal structures of the fibers, the defects and damage to the fibers, through the structures of the yarns, fibers, fabrics to the possibility of analyzing the causes of the various defects in the fabrics. [39]

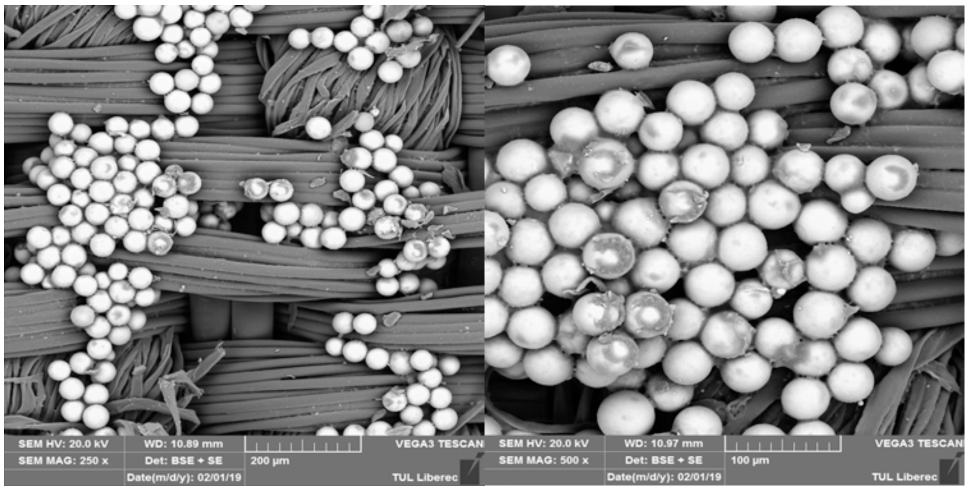


Figure 16: Sample 1: Navy Blue 1000 g/kg* 2 layers

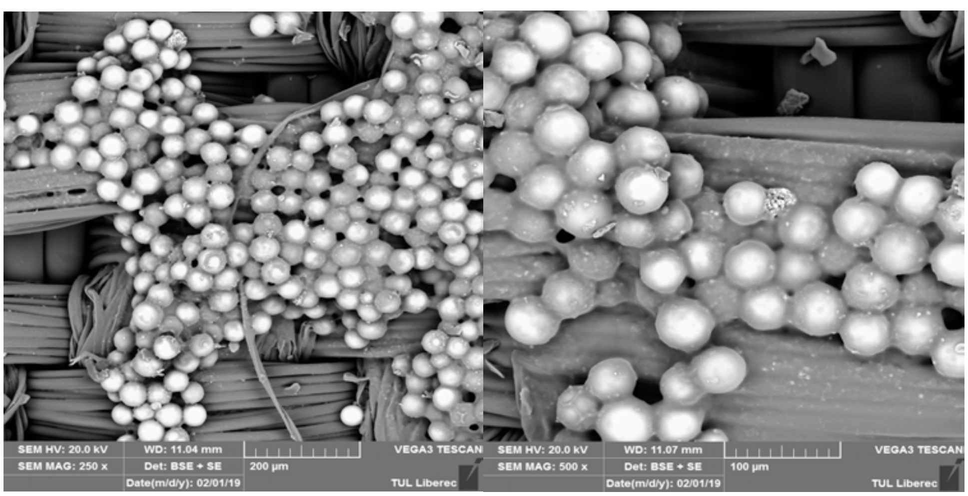


Figure 17: Sample 2: Navy Blue 1000 g/kg* 2 layers with separate curing

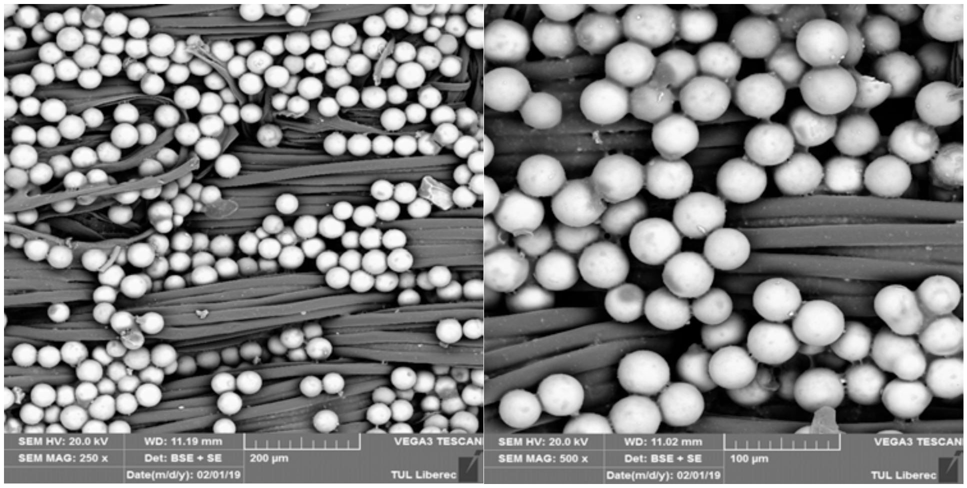


Figure 18: Sample 3: Navy Blue 1000 g/kg* 3 layers

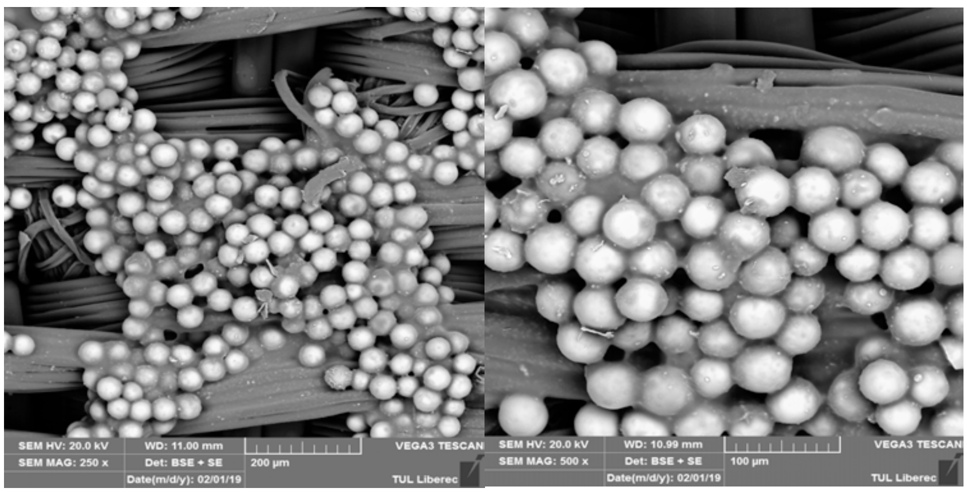


Figure 19: Sample 4: Navy Blue 1000 g/kg* 3 layers with separate curing

Images complement the visibility assessment of selected textile prints. Visibility assessment in this bachelor thesis was chosen as one of the main points that retroreflective printing has to meet. The evaluation was carried out on an electron microscope, it is a microscope created to observe the surfaces of various objects. The device is similar to a light microscope, but here the photons are replaced by electrons and glass lenses are replaced by electromagnetic lenses. The SEM samples must be dry and clean and may be up to 4 cm high and average up to 10 cm.

Microscopic beads are spaced irregularly and fully respect and copy the fabric usage pattern due to the technology used, whereby the reflective print is applied through the screen using squeegees. It brings microscopic balls to the material structure. The balls are different sizes and sometimes deformed. Individual fibers of textile material observed in the pictures. Also, the samples with separate multiple curing are more deformed that samples with curing in one action. Therefore, the effect of retroreflectivity on them is decreasing.

11. SELECTED METHOD FOR MEASURING RETRO REFLECTIVITY

Any devices for measuring the coefficient of retroreflectivity must meet some requirements in the proper standards relating to:

- measuring angles as defined by the 30 m geometry within tolerances specified
- maximum aperture angles
- minimum area of the measured field
- linearity
- suppression of offset by stray light in daylight conditions
- right calibration of devices [40]

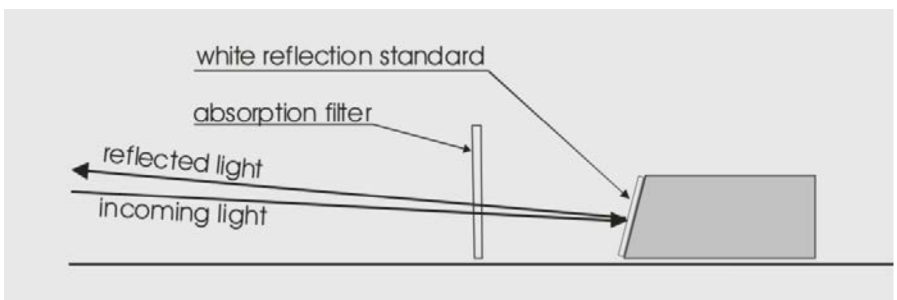


Figure 20: White reflection standard and absorption filter for testing the overall spectral response of a portable instrument. [40]

During experimental work these devises were used:

- KL 1500 LCD

- Illuminance meter T-1

Figure 21: KL 1500 LCD

KL 1500 LCD is a light source. Cold light sources ensure intensive specimen illumination with "cold", i.e. infrared-free light. Via high-quality fiber-optic light guides. [41]

Figure 22: The Konica Minolta T-1 Illuminance Meter [42]

The Konica Minolta T-1 Illuminance Meter is light meter that offers excellent light-measuring capabilities with superb accuracy and simple operation.

Figure 23: Dark room with experimental instrument for measuring retroreflectivity and holder

The measurements were successfully completed through the dark room with experimental instrument for measuring retro reflectivity. Samples were fixed in a special holder to meet the requirements. The Konica Minolta T-1 Illuminance Meter was selected for measuring reflectivity and KL 1500 LCD was a light source.

12. Measurements and diagrams

Each of samples are measured ten times by experimental instrument for measuring retroreflectivity. Average, variance, standard derivation, coefficient of variation and upper/lower CI 95% were calculated for better understanding of illumination of each sample. Graphs consist of two axes: on X Axis is ink concentration that applied on samples; on Y Axis is average of luminous intensity of each measured value, also relationship between average and upper/lower CI 95% are shown on Y Axis. All received values have to be converted from lux to candela and final values are in $mcd/lx/m^2$.

The candela (unit cd) measures the amount of light emitted in the range of a (three-dimensional) angular span. Since the luminous intensity is described in terms of an angle, the distance at which the intensity measured is irrelevant.

Lux (unit lx) is a measure of illumination of a surface. Light meters often measure lux values, lux is a derived unit from lumen, which is a derived unit from candela. Yet, the concept of lux is more easily compared to candela than to lumen.

The difference between lux and candela is that lux measures the illumination of a surface, instead of that of an angle. The net result is that the distance of that surface from the light source becomes an important factor: the more distant that the surface is from the light source, the less it will be illuminated by it. [43]

The luminous intensity I_v in candela (cd) is equal to the luminous flux Φ_v in lumens (lm), divided by 2 times pi times 1 minus cosine of half the apex angle θ in degrees (º):

$$I_{v(cd)} = \Phi_{v(lm)} / (2\pi(1 - \cos(\theta/2)))$$

The luminous flux Φ_V in lumens (lm) is equal to the illuminance E_v in lux (lx) times the surface area A in square meters (m^2) or 4 times pi times the squared sphere radius r in meters (m) [44]:

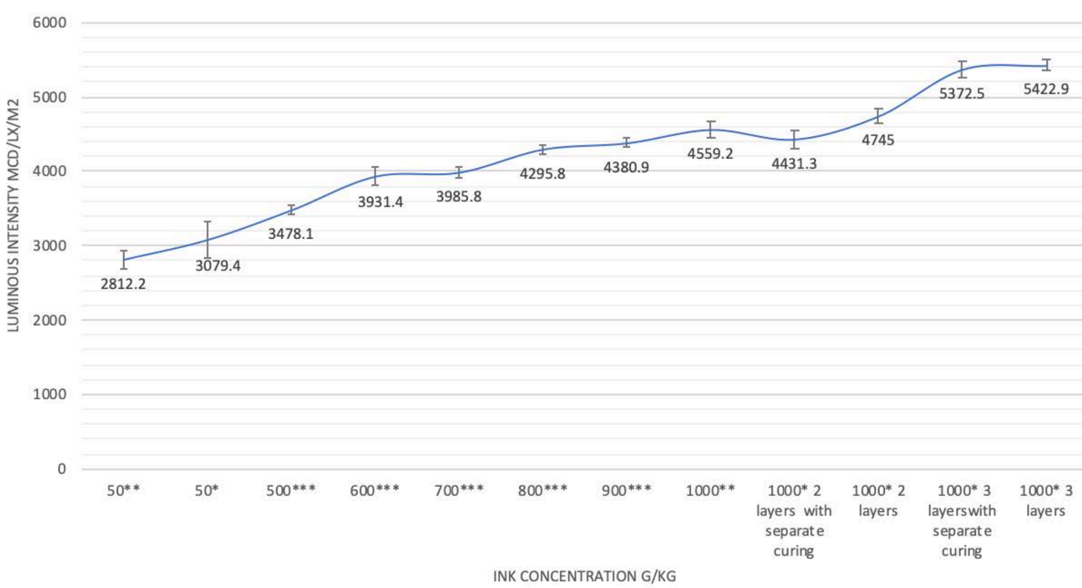
$$\Phi_{V(lm)} = E_{v(lx)} \times 4 \cdot \pi \cdot r^2$$

mcd/lx/m^2	**50g/kg****	**50g/kg***	**500g/kg*****	**600g/kg*****	**700g/kg*****	**800g/kg*****	**900g/kg*****
	2518	2673	3447	3602	3796	4338	4377
	2595	2518	3447	3990	3951	4455	4532
	2711	2711	3525	3912	4028	4300	4416
	2750	3292	3486	4183	3951	4338	4222
	2983	3370	3331	4028	3990	4222	4338
	2983	3254	3447	4028	4106	4338	4416
	2905	3331	3447	3873	4106	4300	4338
	2905	3370	3447	3757	3873	4300	4455
	2944	2983	3602	3951	3990	4145	4377
	2828	3292	3602	3990	4067	4222	4338
Average	2812	3079	3478	3931	3986	4296	4381
Variance	26781.1	108713.8	6604.3	25769.4	9830.6	7152.6	6843.0
Standard deviation	163.6	329.7	81.3	160.5	99.1	84.6	82.7
Coefficient of variation	5.8	10.7	2.3	4.1	2.5	2.0	1.9
CI 95% upper	2929.3	3315.3	3536.2	4046.2	4056.7	4356.3	4440.1
CI 95% lower	2695.1	2843.5	3420.0	3816.6	3914.9	4235.3	4321.7

Table 3: Different quantity of applicated ink for navy blue sample (part 1)

mcd/lx/m^2	1kg*	1kg* 2 layers with separate curing	1 kg* 2 layers	1kg* 3 layers with separate curing	1kg* 3 layers
	4300	4222	4609	5500	5539
	4493	4338	4764	5307	5423
	4416	4338	4687	5423	5500
	4493	4455	4571	5345	5539
	4648	4222	4571	5423	5384
	4687	4493	4764	5307	5423
	4455	4726	4919	5539	5462
	4687	4648	4842	5500	5423
	4687	4416	4726	5345	5229
	4726	4455	4997	5036	5307
Average	4559,8	4431,3	4745	5372,5	5423
Variance	21335.5	27110.5	20742.7	20962.3	9663.9
Standard deviation	146.1	164.7	144.0	144.8	98.3
Coefficient of variation	3.2	3.7	3.0	2.7	1.8
CI 95% upper	4663.7	4549.1	4848.0	5476.1	5493.2
CI 95% lower	4454.7	4313.5	4642.0	5268.9	5352.6

Table 4: Different quantity of applicated ink for navy blue sample (part 2)



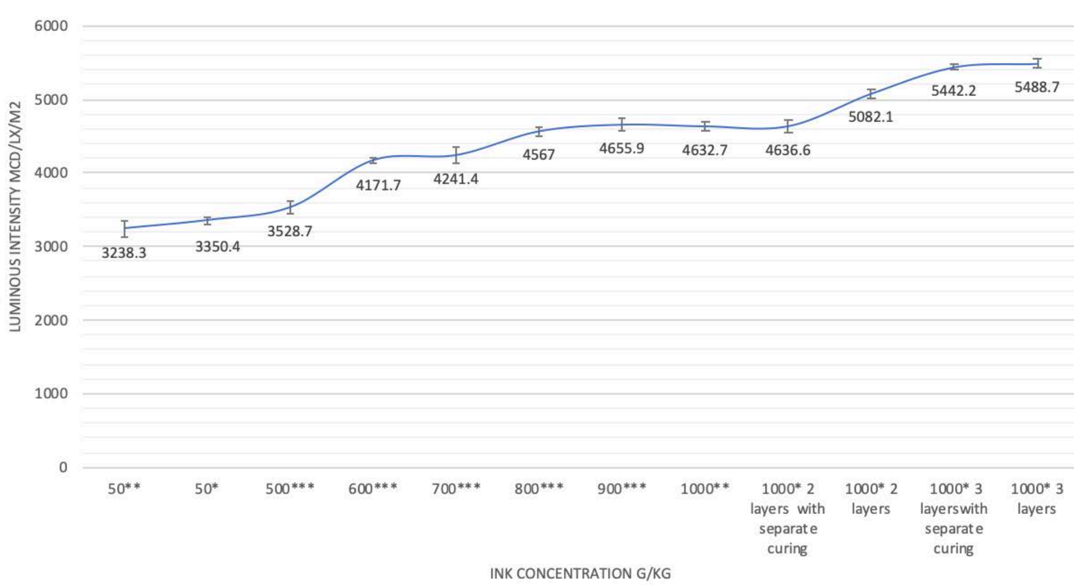
Graph 1: Relationship between average and upper/lower CI 95% for navy blue sample

mcd/lx/m^2	**50g/kg****	**50g/kg***	**500g/kg*****	**600g/kg*****	**700g/kg*****	**800g/kg*****	**900g/kg*****
	2905	3370	3370	4183	4261	4648	4648
	3176	3331	3680	4222	4338	4455	4842
	3176	3370	3602	4145	4261	4455	4803
	3370	3447	3447	4106	4338	4648	4609
	3176	3447	3370	4145	4300	4532	4532
	3138	3370	3525	4183	4183	4687	4726
	3409	3292	3641	4222	4261	4571	4648
	3254	3292	3486	4222	4338	4571	4687
	3370	3215	3564	4183	3873	4455	4609
	3409	3370	3602	4106	4261	4648	4455
Average	3238.3	3350.4	3528.7	4171.7	4241.4	4567.0	4655.9
Variance	25111.8	5081.2	11819.8	2003.6	19121.6	8108.0	13598.8
Standard deviation	158.5	71.3	108.7	44.8	138.3	90.0	116.6
Coefficient of variation	4.9	2.1	3.1	1.1	3.3	2.0	2.5
CI 95% upper	3351.7	3401.4	3606.5	4203.7	4340.3	4631.4	4739.3
CI 95% lower	3124.9	3299.4	3450.9	4139.7	4142.5	4502.6	4572.5

Table 5: Different quantity of applicated ink for diagonal of navy-blue sample (part 1)

$mcd/lx/m^2$	**1kg***	**1kg* 2 layers with separate curing**	**1 kg* 2 layers**	**1kg* 3 layers with separate curing**	**1kg* 3 layers**
	4726	4842	5113	5423	5578
	4648	4726	4958	5462	5500
	4687	4648	5152	5500	5384
	4726	4532	5036	5423	5539
	4648	4493	5074	5423	5578
	4532	4687	5229	5539	5500
	4571	4609	5152	5539	5539
	4609	4648	5113	5384	5462
	4648	4726	5036	5345	5423
	4532	4455	4958	5384	5384
Average	4632.7	4636.6	5082.1	5442.2	5488.7
Variance	5078.9	14030.7	7597.7	4422.4	5357.6
Standard deviation	71.3	118.5	87.2	66.5	73.2
Coefficient of variation	1.5	2.6	1.7	1.2	1.3
CI 95% upper	4683.7	4721.3	5144.5	5489.8	5541.1
CI 95% lower	4581.7	4551.9	5019.7	5394.6	5436.3

Table 6: Different quantity of applicated ink for diagonal of navy-blue sample (part 2)



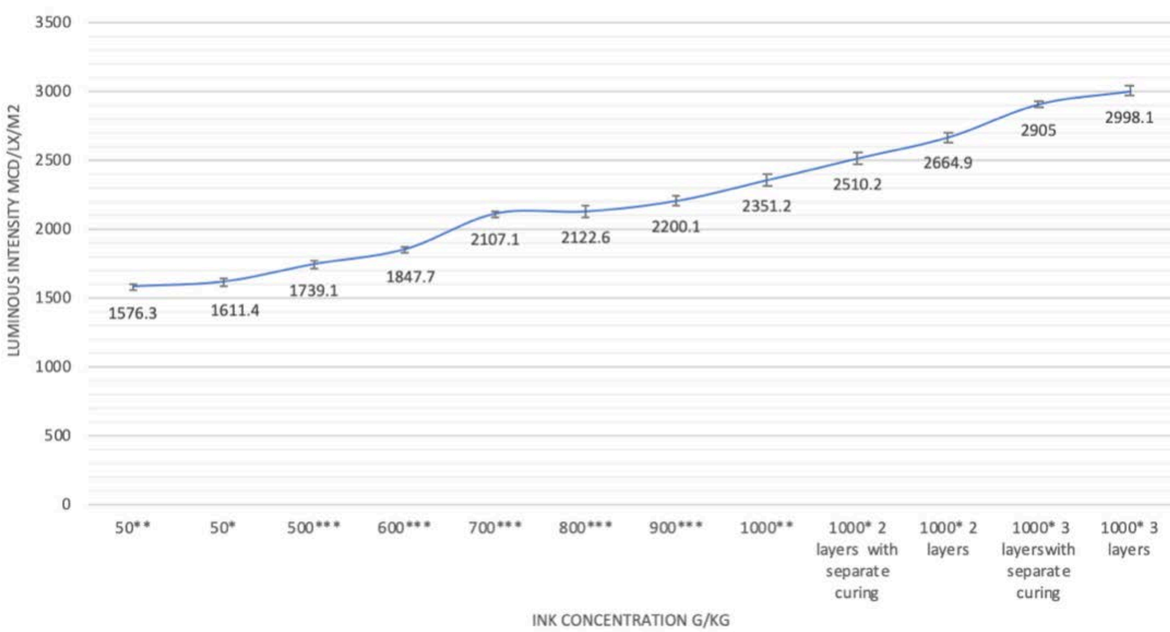
Graph 2: Relationship between average and upper/lower CI 95% for diagonal navy blue sample

mcd/lx/m^2	**50g/kg****	**50g/kg***	**500g/kg*****	**600g/kg*****	**700g/kg*****	**800g/kg*****	**900g/kg*****
	1549	1627	1782	1821	2130	2285	2247
	1588	1627	1704	1859	2092	2092	2247
	1627	1588	1782	1821	2092	2092	2208
	1549	1627	1704	1859	2053	2053	2208
	1588	1627	1743	1821	2130	2130	2130
	1549	1627	1704	1898	2130	2130	2285
	1588	1549	1782	1859	2092	2092	2208
	1549	1627	1782	1821	2092	2092	2130
	1627	1549	1704	1859	2130	2130	2130
	1549	1666	1704	1859	2130	2130	2208
Average	1576.3	1611.4	1739.1	1847.7	2107.1	2122.6	2200.1
Variance	1030.9	1419.6	1504.1	668.9	717.9	3909.2	2955.4
Standard deviation	32.1	37.7	38.8	25.9	26.8	62.5	54.4
Coefficient of variation	2.0	2.3	2.2	1.4	1.3	2.9	2.5
CI 95% upper	1599.3	1638.4	1766.8	1866.2	2126.3	2167.3	2239.0
CI 95% lower	1553.3	1584.4	1711.4	1829.2	2087.9	2077.9	2161.2

Table 7: Different quantity of applicated ink for navy blue sample 45° left side (part 1)

mcd/lx/m^2	**1 kg***	**1kg* 2 layers with separate curing**	**1kg* 2 layers**	**1kg* 3 layers with separate curing**	**1kg* 3 layers**
	2402	2557	2711	2905	2983
	2324	2518	2634	2905	3021
	2324	2595	2711	2944	3021
	2440	2557	2557	2944	2905
	2402	2479	2634	2905	2983
	2402	2557	2673	2866	3060
	2324	2402	2711	2944	2944
	2324	2479	2634	2905	2983
	2285	2518	2711	2866	3060
	2285	2440	2673	2866	3021
Average	2351.2	2510.2	2664.9	2905.0	2998.1
Variance	3039.1	3607.3	2571.0	1014.0	2390.5
Standard deviation	55.1	60.1	50.7	31.8	48.9
Coefficient of variation	2.3	2.4	1.9	1.1	1.6
CI 95% upper	2390.6	2553.2	2701.2	2927.8	3033.1
CI 95% lower	2311.8	2467.2	2628.6	2882.2	2963.1

Table 8: Different quantity of applicated ink for navy blue sample 45° left side (part 2)



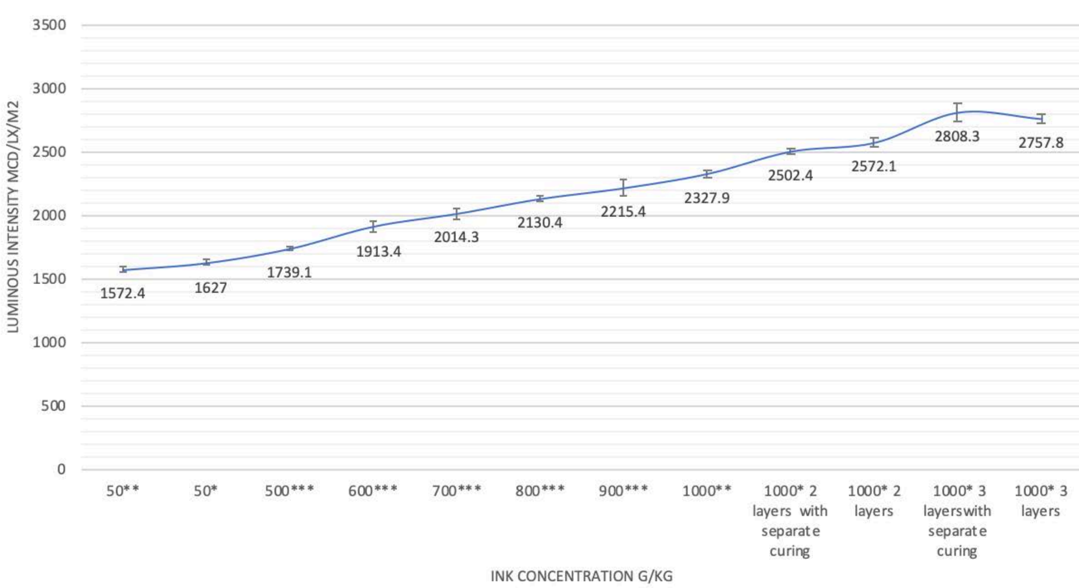
Graph 3: Relationship between average and upper/lower CI 95% for blue sample 45° left side

mcd/lx/m^2	**50g/kg***	**50g/kg****	**500g/kg*****	**600g/kg*****	**700g/kg*****	**800g/kg*****	**900 g/kg*****
	1588	1588	1743	1859	2053	2130	2130
	1549	1666	1704	1859	2014	2092	2130
	1588	1627	1704	1937	1937	2092	2130
	1549	1666	1743	1937	2014	2092	2169
	1549	1627	1782	1859	2053	2169	2285
	1549	1588	1743	1898	2092	2169	2285
	1588	1627	1743	1898	1937	2169	2324
	1627	1627	1743	1859	2053	2092	2324
	1588	1666	1704	2014	2053	2130	2247
	1549	1588	1782	2014	1937	2169	2130
Average	1572.4	1627.0	1739.1	1913.4	2014.3	2130.4	2215.4
Variance	743.6	1014.0	828.1	3740.7	3328.2	1317.6	7288.9
Standard deviation	27.3	31.8	28.8	61.2	57.7	36.3	85.4
Coefficient of variation	1.7	2.0	1.7	3.2	2.9	1.7	3.9
CI 95% upper	1591.9	1649.8	1759.7	1957.2	2055.6	2156.4	2276.5
CI 95% lower	1552.9	1604.2	1718.5	1869.6	1973.0	2104.4	2154.3

Table 9: Different quantity of applicated ink for navy blue sample 45° right side (part 1)

mcd/lx/m^2	1 kg*	1kg* 2 layers with separate curing	1 kg* 2 layers	1kg* 3 layers with separate curing	1 kg* 3 layers
	2363	2479	2634	2983	2711
	2324	2479	2518	2944	2711
	2285	2518	2518	2789	2789
	2285	2518	2518	2789	2789
	2363	2557	2634	2828	2828
	2402	2479	2557	2828	2828
	2324	2479	2595	2711	2711
	2363	2518	2557	2711	2711
	2285	2479	2595	2711	2711
	2285	2518	2595	2789	2789
Average	2327.9	2502.4	2572.1	2808.3	2757.8
Variance	1842.1	743.6	2052.5	8803.3	2636.4
Standard deviation	42.9	27.3	45.3	93.8	51.3
Coefficient of variation	1.8	1.1	1.8	3.3	1.9
CI 95% upper	2358.6	2521.9	2604.5	2875.4	2794.5
CI 95% lower	2297.2	2482.9	2539.7	2741.2	2721.1

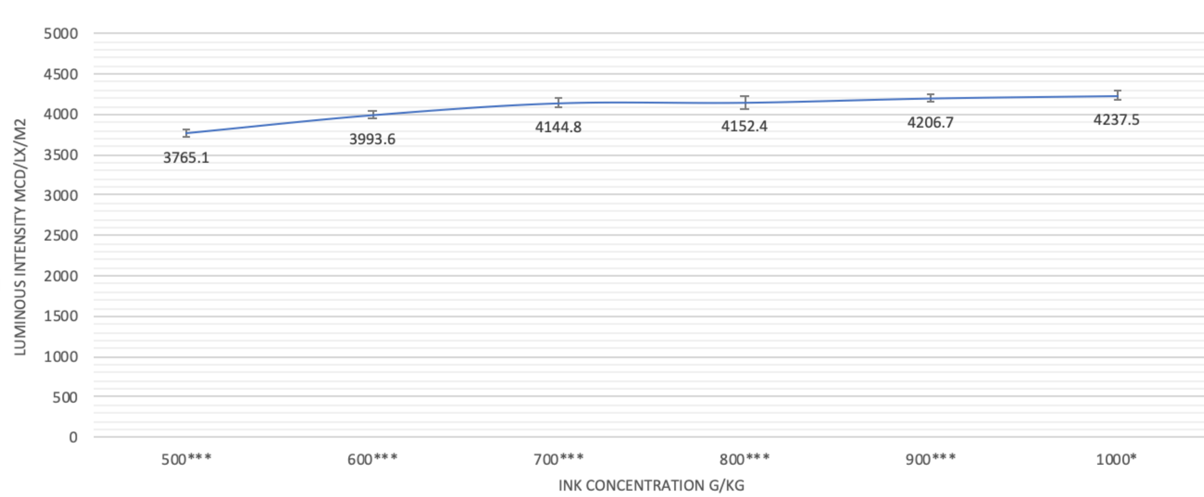
Table 10: Different quantity of applicated ink for navy blue sample 45° right side (part 2)



Graph 4: Relationship between average and upper/lower CI 95% for navy blue sample 45° right side

mcd/lx/m^2	**500g/kg***	**600g/kg***	**700g/kg***	**800g/kg***	**900g/kg***	**1 kg***
	3719	3912	4106	4145	4106	4338
	3796	3990	4145	4261	4222	4377
	3719	4028	4145	4106	4300	4183
	3796	3990	4145	4145	4183	4145
	3873	3951	4261	4067	4183	4261
	3680	4067	4145	3873	4145	4338
	3796	4106	4067	4261	4261	4183
	3835	3951	4106	4183	4145	4145
	3680	3951	4067	4222	4222	4222
	3757	3990	4261	4261	4300	4183
Average	3765.1	3993.6	4144.8	4152.4	4206.7	4237.5
Variance	4243.7	3482.9	4680.2	14309.2	4411.6	7386.3
Standard deviation	65.1	59.0	68.4	119.6	66.4	85.9
Coefficient of variation	1.7	1.5	1.7	2.9	1.6	2.0
CI 95% upper	3811.7	4035.8	4193.7	4238.0	4254.2	4299.0
CI 95% lower	3718.5	3951.4	4095.9	4066.8	4159.2	4176.0

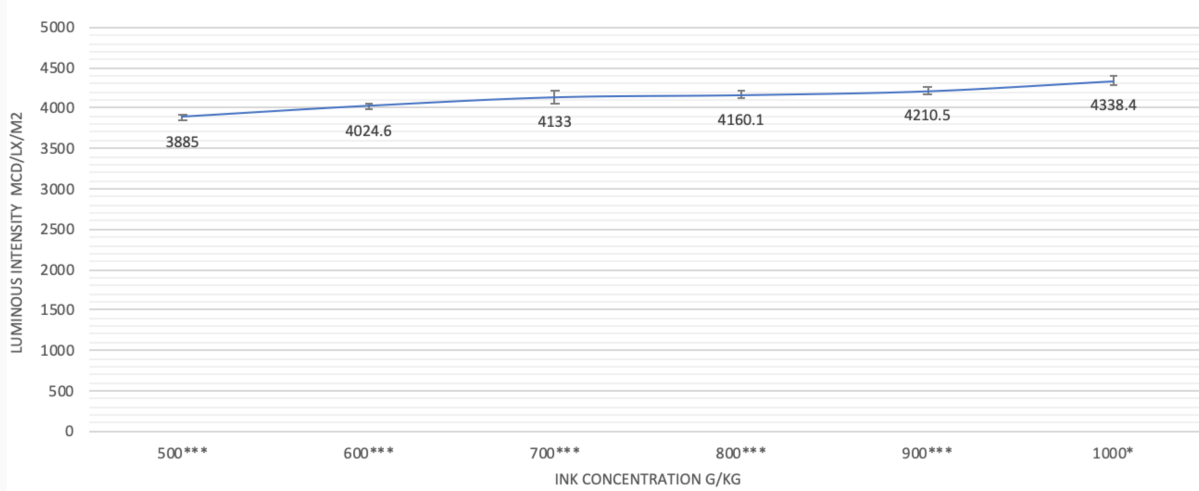
Table 11: Different quantity of applicated ink for lava sample



Graph 5: Relationship between average and upper/lower CI 95% for lava sample

mcd/lx/m^2	**500g/kg*** **	**600g/kg*** **	**700g/kg*** **	**800g/kg*** **	**900g/kg*** **	**1 kg***
	3757	3990	4222	4145	4338	4338
	3873	4067	4183	4261	4106	4300
	3912	4067	3873	4183	4222	4338
	3912	3951	4106	4028	4261	4416
	3835	3990	4261	4145	4183	4455
	3835	4028	4145	4145	4145	4455
	3912	3990	4183	4183	4145	4222
	3951	4067	4145	4106	4222	4300
	3951	3990	3990	4222	4300	4338
	3912	4106	4222	4183	4183	4222
Average	3885.0	4024.6	4133.0	4160.1	4210.5	4338.4
Variance	3684.0	2470.7	14032.4	4071.9	5343.8	7028.9
Standard deviation	60.7	49.7	118.5	63.8	73.1	83.8
Coefficient of variation	1.6	1.2	2.9	1.5	1.7	1.9
CI 95% upper	3928.4	4060.2	4217.7	4205.7	4262.8	4398.4
CI 95% lower	3841.6	3989.0	4048.3	4114.5	4158.2	4278.4

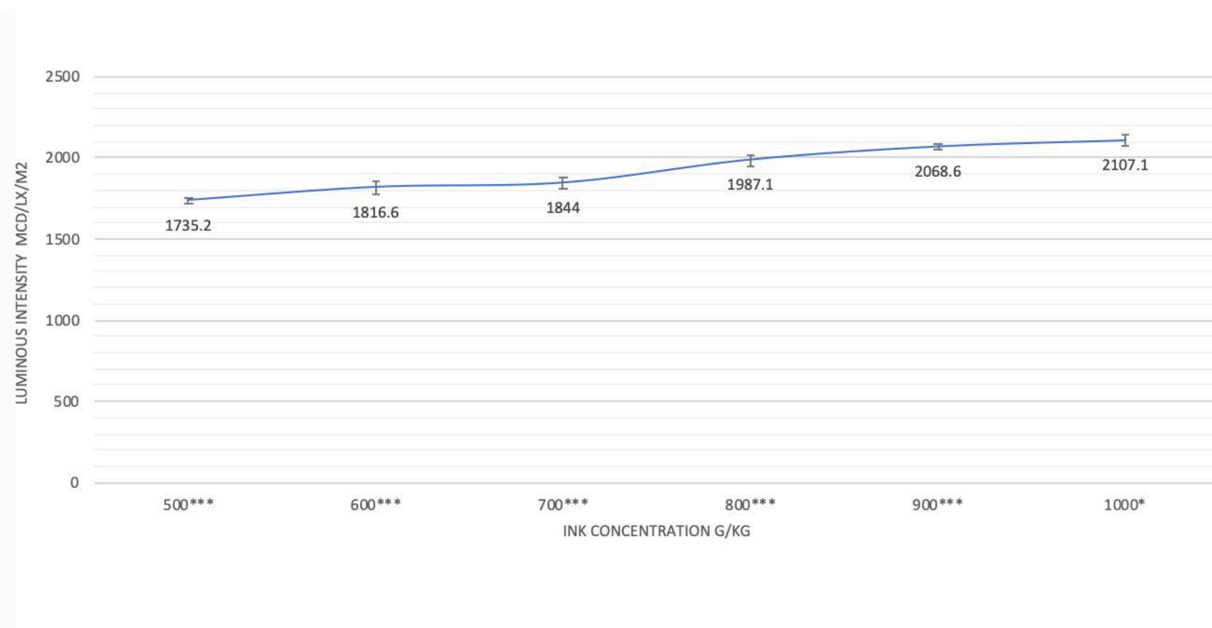
Table 12: Different quantity of applicated ink for diagonal of lava



Graph 6: Relationship between average and upper/lower CI 95% for diagonal lava sample

mcd/lx/m^2	**500g/kg*** **	**600g/kg*** **	**700g/kg*** **	**800g/kg*** **	**900 g/kg*** **	**1 kg***
	1743	1782	1782	2053	2053	2169
	1704	1859	1821	2014	2092	2169
	1743	1782	1821	2053	2053	2092
	1743	1704	1821	1937	2092	2053
	1782	1859	1898	1975	2014	2092
	1704	1859	1898	1937	2053	2130
	1743	1859	1859	2014	2092	2130
	1704	1859	1821	2014	2053	2053
	1743	1782	1898	1937	2092	2053
	1743	1821	1821	1937	2092	2130
Average	1735.2	1816.6	1844.0	1987.1	2068.6	2107.1
Variance	608.4	2808.7	1718.0	2338.1	743.6	2052.5
Standard deviation	24.7	53.0	41.4	48.4	27.3	45.3
Coefficient of variation	1.4	2.9	2.2	2.4	1.3	2.2
CI 95% upper	1752.8	1854.5	1873.7	2021.7	2088.1	2139.5
CI 95% lower	1717.6	1778.7	1814.3	1952.5	2049.1	2074.7

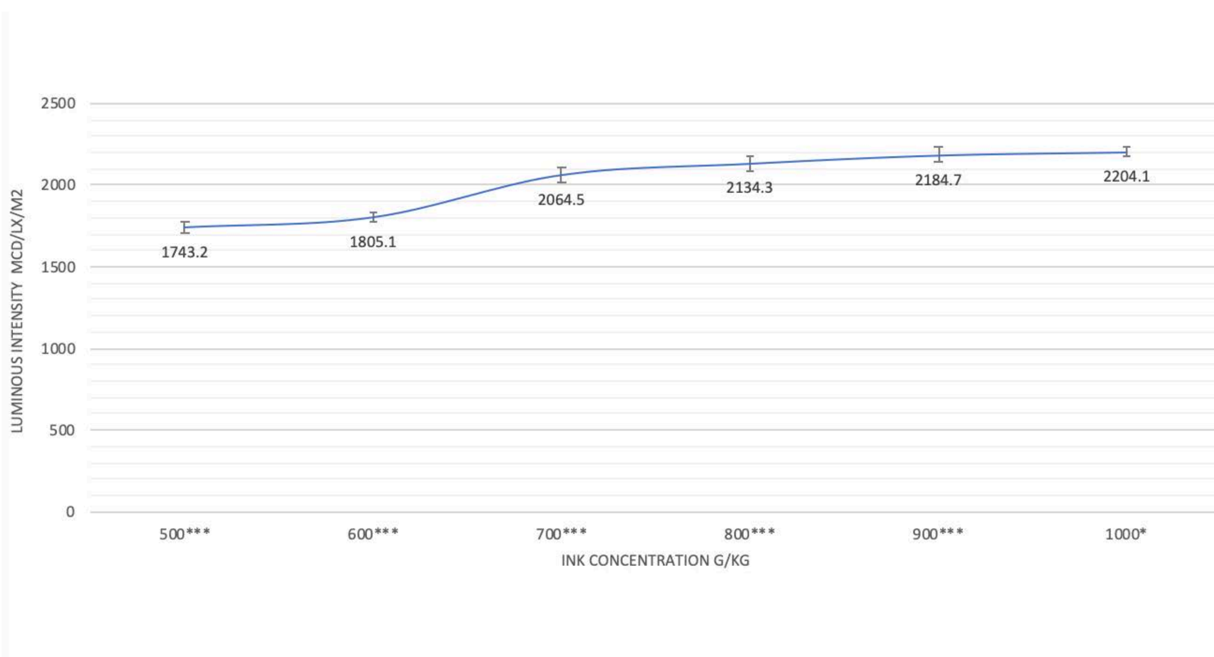
Table 13: Different quantity of applicated ink for lava sample 45° left side



Graph 7: Relationship between average and upper/lower CI 95% for lava sample 45° left side

mcd/lx/m^2	**500g/kg***	**600g/kg***	**700g/kg***	**800g/kg***	**900 g/kg***	**1 kg***
	1782	1782	2130	2053	2247	2169
	1782	1859	2130	2130	2092	2169
	1704	1859	2092	2247	2130	2208
	1782	1859	2092	2169	2247	2247
	1666	1782	2014	2208	2208	2208
	1782	1821	2014	2169	2130	2208
	1704	1821	1937	2130	2130	2169
	1782	1743	2130	2092	2247	2247
	1666	1743	2053	2092	2247	2247
	1782	1782	2053	2053	2169	2169
Average	1743.2	1805.1	2064.5	2134.3	2184.7	2204.1
Variance	2669.5	2059.4	4000.5	4152.9	3764.9	1166.1
Standard deviation	51.7	45.4	63.2	64.4	61.4	34.1
Coefficient of variation	3.0	2.5	3.1	3.0	2.8	1.5
CI 95% upper	1780.2	1837.6	2109.7	2180.4	2228.6	2228.5
CI 95% lower	1706.2	1772.6	2019.3	2088.2	2140.8	2179.7

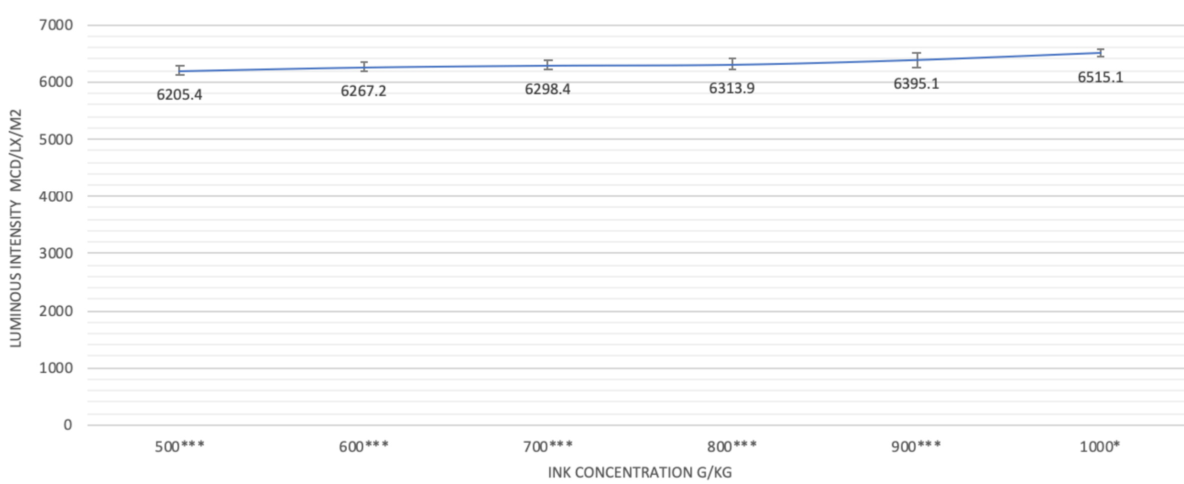
Table 14: Different quantity of applicated ink for lava sample 45° right side



Graph 8: Relationship between average and upper/lower CI 95% for lava sample 45° right side

mcd/lx/m²	500g/kg***	600g/kg***	700g/kg***	800g/kg***	900g/kg***	1kg*
	6314	6236	6198	6353	6236	6391
	6314	6120	6198	6430	6081	6624
	6120	6236	6159	6198	6198	6391
	6198	6314	6159	6236	6469	6507
	6081	6391	6469	6275	6662	6546
	6275	6391	6430	6353	6353	6585
	6198	6120	6275	6120	6507	6624
	6120	6275	6391	6430	6430	6546
	6120	6391	6236	6198	6546	6430
	6314	6198	6469	6546	6469	6507
Average	6205.4	6267.2	6298.4	6313.9	6395.1	6515.1
Variance	8632.3	10922.4	16396.5	17325.7	31473.4	7632.1
Standard deviation	92.9	104.5	128.0	131.6	177.4	87.4
Coefficient of variation	1.5	1.7	2.0	2.1	2.8	1.3
CI 95% upper	6271.9	6342.0	6390.0	6408.1	6522.0	6577.6
CI 95% lower	6138.9	6192.4	6206.8	6219.7	6268.2	6452.6

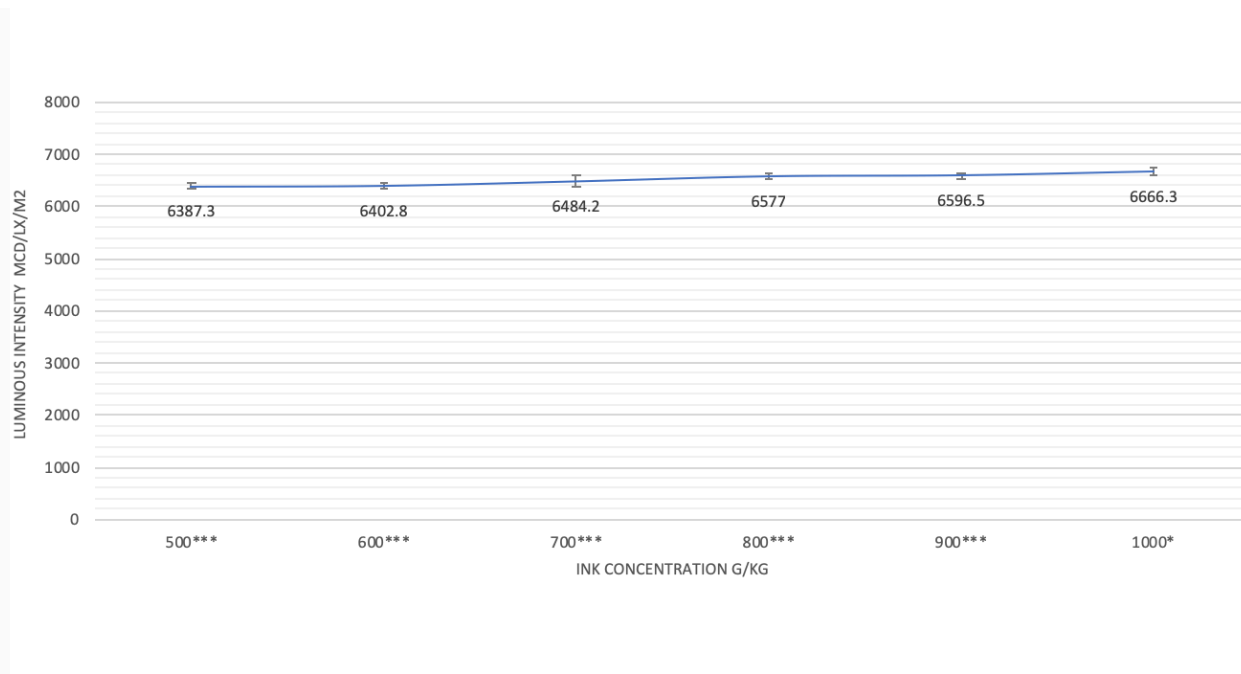
Table 15: Different quantity of applicated ink for white sample



Graph 9: Relationship between average and upper/lower CI 95% for white sample

mcd/lx/m^2	**500g/kg*** **	**600g/kg*** **	**700g/kg*** **	**800g/kg*** **	**900g/kg*** **	**1kg***
	6236	6430	6469	6507	6662	6779
	6314	6314	6391	6469	6469	6546
	6507	6353	6507	6546	6546	6817
	6391	6391	6081	6507	6701	6662
	6391	6391	6546	6662	6701	6585
	6469	6507	6469	6662	6546	6662
	6391	6391	6585	6701	6585	6624
	6430	6236	6624	6507	6585	6779
	6391	6469	6624	6585	6624	6585
	6353	6546	6546	6624	6546	6624
Average	6387.3	6402.8	6484.2	6577.0	6596.5	6666.3
Variance	5813.6	8343.5	25458.4	6602.7	5673.2	8824.5
Standard deviation	76.2	91.3	159.6	81.3	75.3	93.9
Coefficient of variation	1.2	1.4	2.5	1.2	1.1	1.4
CI 95% upper	6441.8	6468.1	6598.3	6635.1	6650.4	6733.5
CI 95% lower	6332.8	6337.5	6370.1	6518.9	6542.6	6599.1

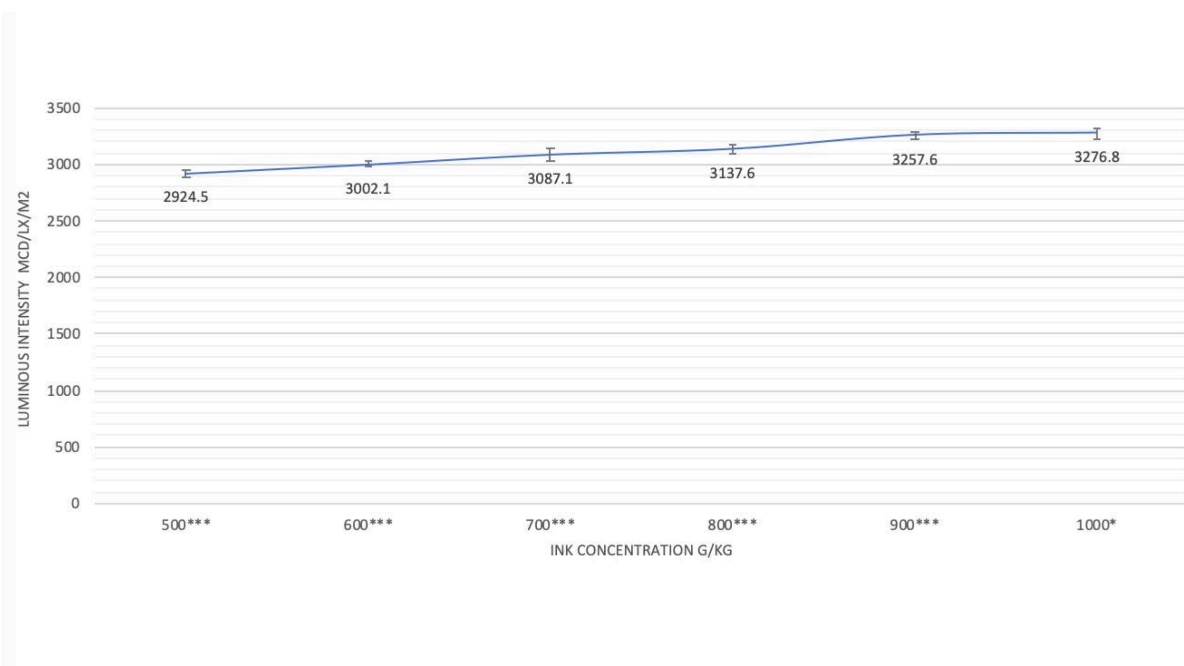
Table 16: Different quantity of applicated ink for diagonal of white sample



Graph 10: Relationship between average and upper/lower CI 95% for diagonal of white sample

mcd/lx/m^2	**500g/kg*** **	**600g/kg*** **	**700g/kg*** **	**800g/kg*** **	**900g/kg*** **	**1 kg***
	2983	3060	2983	3060	3292	3292
	2866	3060	3060	3176	3331	3176
	2905	2983	3060	3099	3215	3254
	2905	3021	3021	3099	3215	3176
	2983	3021	3021	3138	3254	3215
	2983	2983	3099	3176	3254	3331
	2905	2944	3099	3215	3254	3292
	2866	2983	3176	3099	3331	3292
	2944	2983	3176	3138	3215	3370
	2905	2983	3176	3176	3215	3370
Average	2924.5	3002.1	3087.1	3137.6	3257.6	3276.8
Variance	2112.5	1402.1	5004.1	2322.9	2139.6	5073.7
Standard deviation	46.0	37.4	70.7	48.2	46.3	71.2
Coefficient of variation	1.6	1.2	2.3	1.5	1.4	2.2
CI 95% upper	2957.4	3028.9	3137.7	3172.1	3290.7	3327.8
CI 95% lower	2891.6	2975.3	3036.5	3103.1	3224.5	3225.8

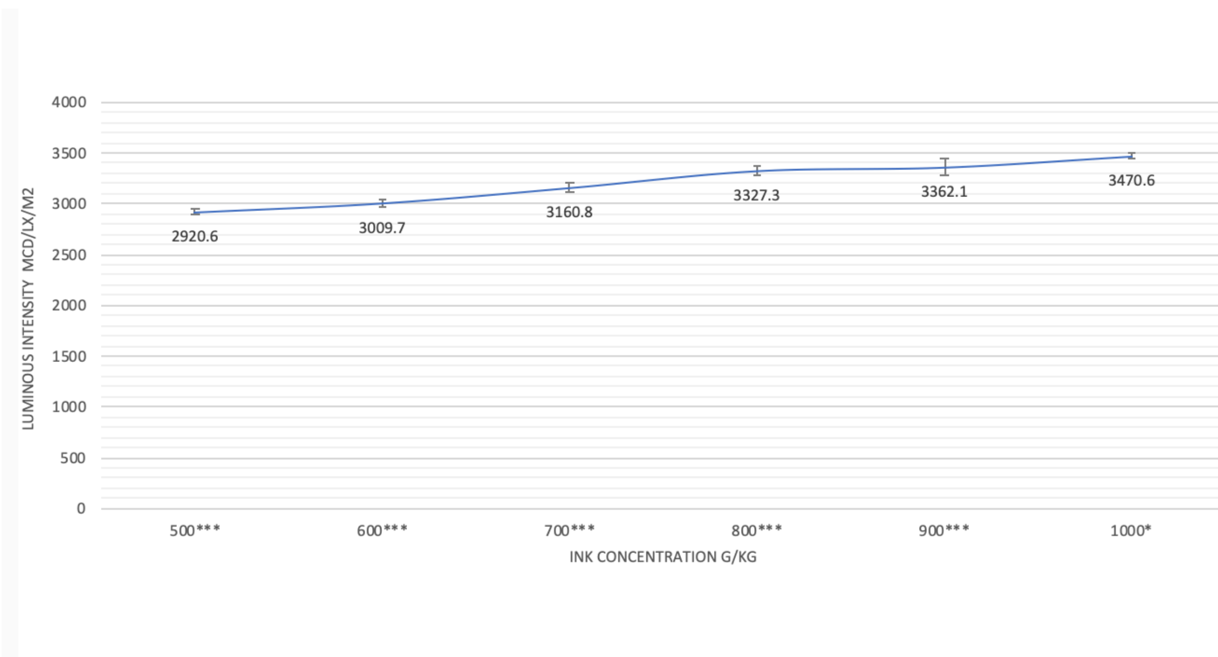
Table 17: Different quantity of applicated ink for white sample 45° left side



Graph 11: Relationship between average and upper/lower CI 95% for white sample 45° left side

mcd/lx/m^2	**500g/kg*** **	**600g/kg*** **	**700g/kg*** **	**800g/kg*** **	**900 g/kg*** **	**1 kg***
	2905	3060	3099	3292	3099	3525
	2905	3060	3215	3331	3447	3486
	2866	2983	3176	3215	3331	3447
	2983	2944	3176	3254	3409	3409
	2944	2944	3099	3331	3292	3409
	2944	3021	3060	3331	3447	3486
	2866	3060	3060	3370	3409	3486
	2983	3021	3254	3370	3447	3525
	2905	3021	3215	3409	3370	3486
	2905	2983	3254	3370	3370	3447
Average	2920.6	3009.7	3160.8	3327.3	3362.1	3470.6
Variance	1757.6	2003.6	5741.1	3490.7	11250.1	1730.0
Standard deviation	41.9	44.8	75.8	59.1	106.1	41.6
Coefficient of variation	1.4	1.5	2.4	1.8	3.2	1.2
CI 95% upper	2950.6	3041.7	3215.0	3369.6	3438.0	3500.4
CI 95% lower	2890.6	2977.7	3106.6	3285.0	3286.2	3440.8

Table 18: Different quantity of applicated ink for white sample 45° right side



Graph 12: Relationship between average and upper/lower CI 95% for white sample 45° right side

$mcd/lx/m^2$	**1 kg***	**1 kg* 2 layers**	**1 kg* diagonal**	**1 kg* 2 layers diagonal**
	3447	5190	3447	5229
	3370	5268	3990	5036
	3912	5229	3835	5152
	3912	4997	3757	5113
	3564	5229	3796	5229
	3370	5229	3912	5152
	3409	5036	3990	5152
	3176	4919	3835	5268
	3409	4958	3912	5268
	3796	5036	3951	5036
Average	3536.5	5109.1	3842.5	5163.5
Variance	64002.7	17460.5	25661.2	7320.1
Standard deviation	253.0	132.1	160.2	85.6
Coefficient of variation	7.2	2.6	4.2	1.7
CI 95% upper	3717.5	5203.6	3957.1	5224.7
CI 95% lower	3355.5	5014.6	3727.9	5102.3

Table 19: Different quantity of applicated ink for dark khaki sample

mcd/lx/m^2	**900 g/kg*** left**	**1 kg* left**	**900 g/kg*** right**	**1 kg* right**
	2130	2402	2247	2324
	2130	2324	2130	2324
	2130	2324	2092	2324
	2169	2402	2130	2324
	2285	2324	2130	2402
	2285	2402	2247	2479
	2324	2402	2247	2402
	2324	2479	2285	2402
	2130	2324	2285	2363
	2247	2402	2247	2363
Average	2215.4	2378.5	2204.0	2370.7
Variance	7288.9	2749.2	5498.9	2612.2
Standard deviation	85.4	52.4	74.2	51.1
Coefficient of variation	3.9	2.2	3.4	2.2
CI 95% upper	2276.5	2416.0	2257.0	2407.3
CI 95% lower	2154.3	2341.0	2151.0	2334.1

Table 20: Different quantity of applicated ink for dark khaki sample 45° left and right side

mcd/lx/m^2	**direct**	**diagonal**	**45°C right**	**45°C left**
	16695	17082	10962	11311
	16579	17121	11039	11427
	16656	17353	10768	11620
	16888	17315	10807	11466
	16850	17469	10846	11620
	16656	17547	10652	11194
	16850	17276	10730	11427
	16579	17082	11078	11039
	16734	17315	11117	11156
	16579	17469	10923	11233
Average	16706.6	17302.9	10892.2	11349.3
Variance	14320.5	27663.4	24583.5	38334.7
Standard deviation	119.7	166.3	156.8	195.8
Coefficient of variation	0.7	1.0	1.4	1.7
CI 95% upper	16792.2	17421.9	11004.4	11489.4
CI 95% lower	16621.0	17183.9	10780.0	11209.2

Table 21: Measurements of retroreflective material (tape)

13. CONCLUSION OF MEASUREMENTS

According to achieved results retroreflective material showed the best results, as for printed samples navy blue and white samples were selected for further processing. Moreover, a sample with fiber material of 52 % CO 48% PA was selected (the material is used as raw material for making raincoats) and has to meet requirements for further processing.

14. SILICONE- TREATED WATER REPELLENT FABRIC

After treatment of processed material was provided by silicone water repellent. Silicone-based DWRs have been known as one of the most environmentally friendly options for achieving water repellency of fabrics. The required performance level of the repellent finishes depends on the expected usage as apparel goods and other important factors such as durability to laundering and dry cleaning, resistance to abrasion and fabric breathability.

Silicone-based water repellant finishes are more durable than wax and melamine’s repellents, but less durable than fluorochemical finishes. Recently, organ-modified silicones with various reactive functional groups have also become available, and they are demonstrating greater potential durability. However, their use as a water repellent is not common and they are

commonly used as softeners. From the cost point of view, silicones are more costly than wax repellents and less expensive than fluorochemical repellents. Treatment with silicones, on the other side, requires a relatively small amount of additive, so less chemical used.
There some advantages and disadvantages of silicone water repellents.

Advantages:

- A high degree of water repellency at relatively low (0,5%-1%) on weight of fabric concentration
- Very soft fabric hand, resistance to water-borne stains
- Resistance to UV, heat and oxidative degeneration
- Permeability to gas and water vapour, no significant hindrance to breathability of fabric
- Improved sewability, shape retention, and appearance and feel of pile fabric
- High spreading and wetting capabilities
- Degradable in environment

Disadvantages:

- Moderate durability to laundering (through hydrolysis of siloxane and rupture of the film)
- Moderate durability to dry cleaning (absorption of surfactants)
- Increased pilling and seam slippage
- Reduced repellency if excessive amounts are applied
- No oil and soil repellent

As mentioned above water-resistant means that material has a repellent coating on the outside to stop water absorption. The material will breathable, soft enough and meet basic requirements for everyday use. [45]

15. Design

15.1. Inspiration

There are two inspiration elements taking place in this bachelor: design of prints and design of outer clothes.

First one is the sun's magnetic field for print designs. The magnetic system is important for understanding the nature of space throughout the cosmic system: The sun's magnetic field is responsible for everything from the solar explosions that cause space weather on Earth – such as auroras – to the interplanetary magnetic field and radiation through which our spacecraft journeying around the solar system must travel. For observing invisible fields of the sun, first it is important to understand how it works. The sun is made of plasma, a gas-like nature of matter in which electrons and ions have divided, creating a super-hot mix of charged particles. When charged particles migrate, they consistently create magnetic fields, which in turn have an extra effect on how the particles move. The plasma in the sun, consequently, sets up a complicated system of cause and effect in which plasma flows inside the sun – churned up by the enormous heat generated by nuclear fusion at the center of the sun – create the sun's magnetic fields. [46]

Second one is hyperbaric welding. Diving suit for underwater welding is chosen as a basic idea for designs of outer clothes. The process of underwater welding directly exposes the diver and wire to the surrounding elements and water. The most common material, that is welded, is steel. The applications of hyperbaric welding are different. The applications of hyperbaric welding are different: offshore oil platforms, repair ships etc.

Reflective inks were selected taking into account both of inspiration elements adopted to ready to wear garments. The Sun is the main important source of energy for life in the Earth and the biggest light source in universe. As for underwater welding, divers using fluorescent and reflective materials to be visible at the depth. In conclusion two of the design ideas coming together.

15.2. Mood board

Mood board of the general idea: underwater welding and magnetic field of the sun with an urban combination. Color selection of final garments created by the connection of different inspiration sources.

Figure 24: The general idea mood board

15.3. Process of making a design and final design

Inspiration idea for reflective prints is based of studying magnetic field of the sun as mentioned above. Therefore, the computer models to generate a sun's magnetic field made by NASA's Solar Dynamics Observatory was selected for further processing.

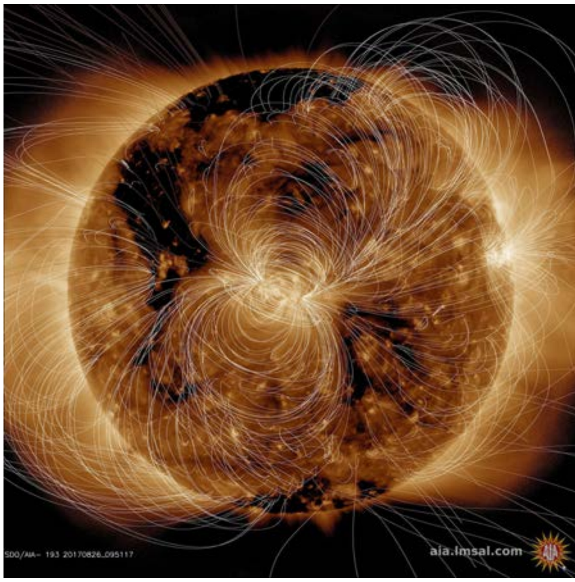


Figure 25: Original illustration [46]

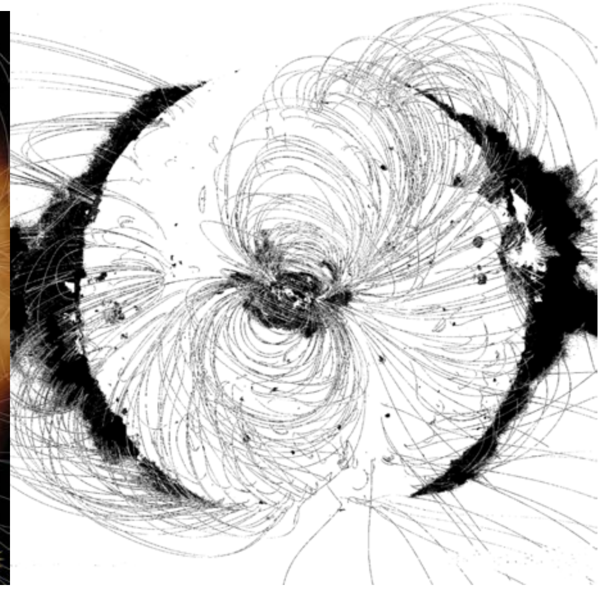


Figure 26: Illustration processed in Adobe Photoshop CC 2017

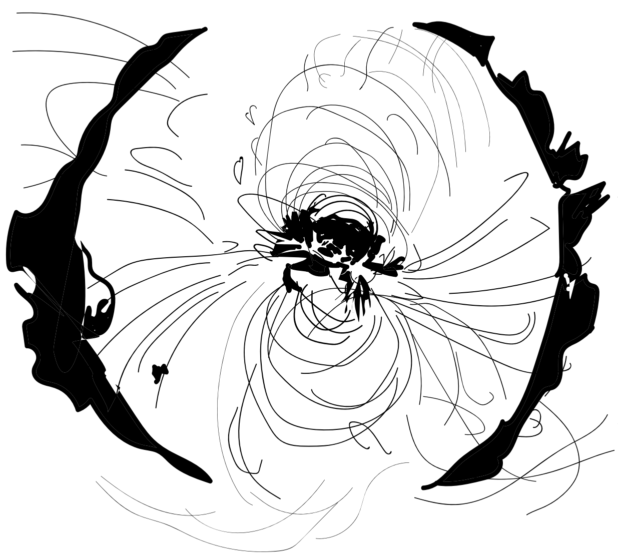


Figure 27: Illustration №1 processed in Adobe Illustration CC 2017

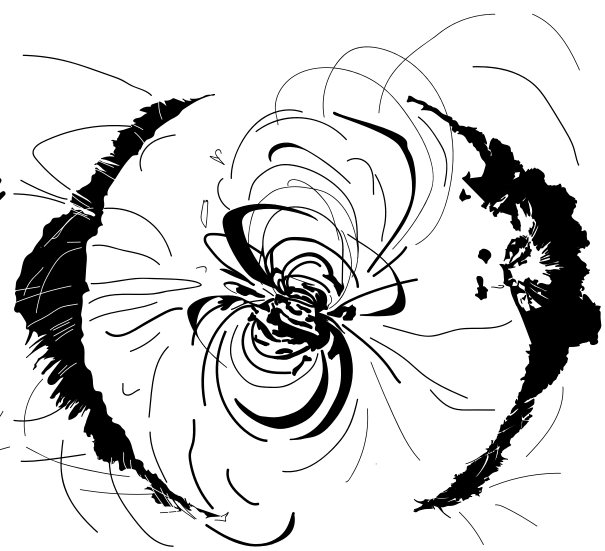


Figure 28: Illustration №2 processed in Adobe Illustration CC 2017

The illustration on Figure 53 is selected according to the particularity of reflective inks (prints with reflective inks are more visible when covered area is wider). Therefore, the idea is managed by technological and design appearances.

15.4. TECHWEAR

Acronym is recognized as one of the foundational guiders of techwear. The company never advertises and with no public relations strategy to speak of, its founders are tough to reach. Founded in 1994 by Errolson Hugh and Michaela Sachenbacher, Acronym is an incredibly lean and agile development. The founders are as likely to refer to themselves as a guerrilla unit as a clothing company, but since 2002, they've produced their own apparel label. It's sleek and futuristic, tough, functional and creative. And though the technical nature of the garments is a selling point in certain markets. [47]

Figure 29: Jackets from next generation Acronym [47]

15.5. Wearing apparel with retroreflective elements for casual clothing - outer clothes

15.5.1. Technical description for both garments

The Front of the garment:

1. **Sleeve Seam**

The seam along the back of the sleeve where the upper sleeve and the undersleeve are joined.

2. **Sleeve Head**

The point of the sleeve just to the other side of the shoulder seam. This is one of the important fitting points on any jacket.

3. **Sleeve Front**

The portion of the sleeve that faces out on the front of the jacket

4. **Front Collar**

All collars have a front and a back, as well as an upper and an under. This part of the collar is on the top of the jacket. On top of the collar is the front upper collar.

5. **Back Facing**

The bit of fabric between the lining and the under collar.; it attaches to the front facing to finish the opening of the jacket.

6. **Side Seam**

The point where the side front and the side back pieces join. This seam goes from under the arm to the hem.

7. **Garment Front**

The portion of the front from the shoulder or yoke to the hem, closest to the collar and front opening

The Back of the garment:

8. **Upper Sleeve**

Most jackets have a sleeve made up of more than one single piece. The top portion is the upper sleeve.

9. Under Sleeve

The lower part of the multi-piece sleeve.

10. Armscye

The curved opening that goes around the arm (from over the shoulder to under the armpit); it is pronounced arm-sigh.

11. Shoulder

The shoulder, along with the armscye and sleeve head, is another major point of fitting in any jacket. It is the seam that runs from the sleeve to the neck.

12. Back Upper Collar

The top portion of the back side of the collar.

13. Garment Back

The section of fabric between the side seam and the back seam.

14. Garment Hem

The bottom of the jacket, all the way around the entire jacket.

15. Sleeve Hem

The bottom of the sleeve, around your wrist area

Details of the garment:

16. Patch pocket with press studs

Patch Pockets are created by attaching a pre-cut piece of material and sewing them, like a patch, to the outside of a garment, instead of constructing inset pockets.

17. Invisible zipper

Invisible zippers have the teeth hidden behind a tape

18. Zipper

Fastener consisting of two rows of metal or plastic teeth on strips of tape and a sliding piece that closes an opening by drawing the teeth together

19. Press stud

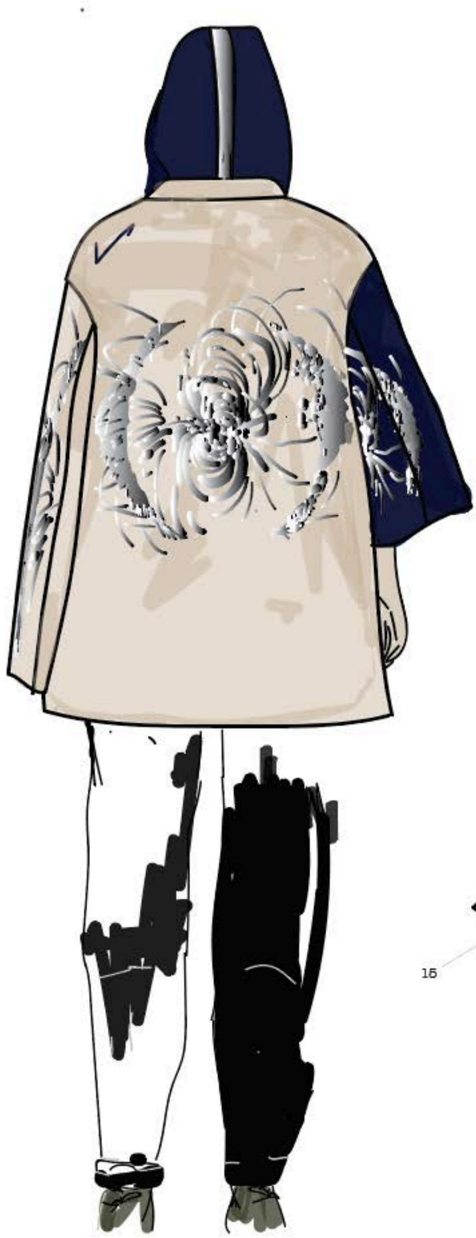
A set of two metal or plastic pieces that fit tightly together when pressed [48] [49]

20. Retroreflective tape

21. LED flexible strip

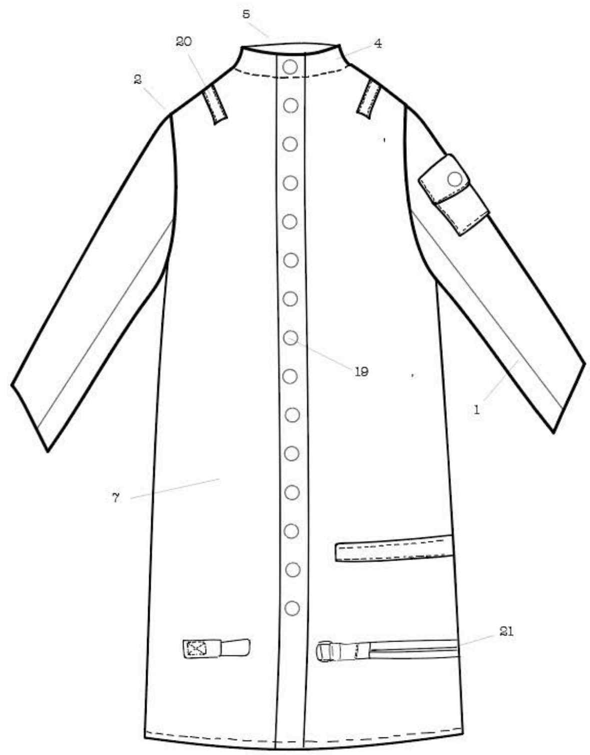
LED flexible strip is a flexible circuit board populated by surface mounted light-emitting diodes (SMD LEDs) and other components that usually comes with an adhesive backing. [50]

15.5.2. Sketches

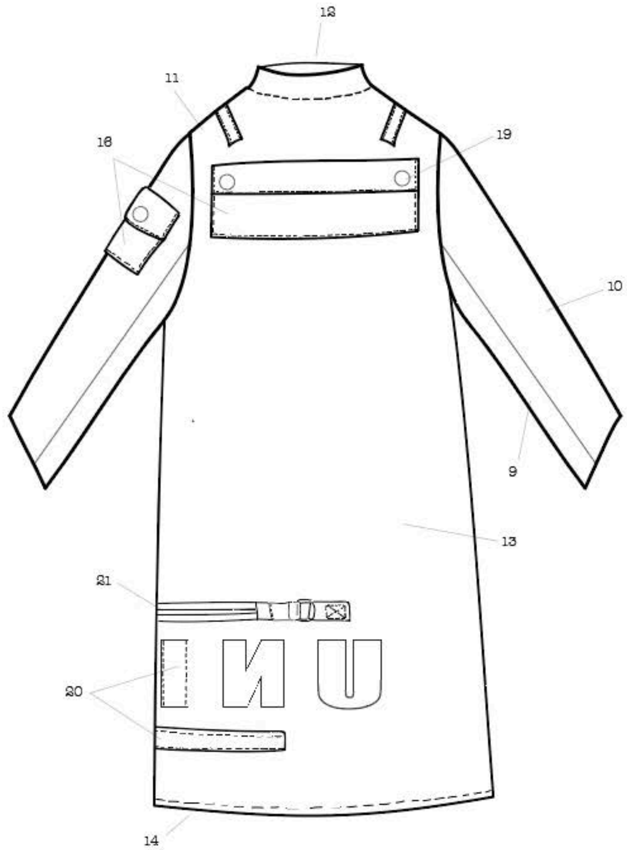


ANORAK

Parka



Parka



CONCLUSION

In this bachelor thesis was trying to obtain several aims in the usage of high visibility materials in regular life. The answers were found during the researching process.

Retroreflective materials have better reflectivity than retroreflective inks, nevertheless, inks give the opportunity to print almost any kind of designs. The retroreflective prints and tape, that were used, meet the minimum coefficient in retroreflectivity described in the EN ISO 20471.
Also, the retroreflective material can be used with retroreflective prints to increase the safety of the consumer. The placement for prints is an important factor that can influence the visuality of garment. Moreover, the design area should be full enough to increase reflectivity.
Accordingly to achieved results, the retroreflective inks should be used more for safety and design purposes.

The difficulty of this work was to apply retroreflective inks herewith not decrease the level of reflectivity. The optimal variants were found after a number of experiments.

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